Renewable Energy 66 (2014) 251–256

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Development of olive stone quality system based on biofuel energetic parameters study

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ARTICLE INFO

Article history:
Received 10 September 2013
Accepted 8 December 2013
Available online 7 January 2014

Keywords:
Quality index
Olive residues
Solid biofuels
Proximate analysis
Ultimate analysis

ABSTRACT

In Andalusia (Southern Spanish region), olive industry presents a high potential of solid biofuel production because of residues generated from olive groves and those by olive oil industries. In this region, 25% of residual biomass is produced by olive sector and olive stone residues are among the most important since its production is over 450,000 tons/year.

The objective of this research is to provide unambiguous and clear classification principles for olive stone residues based on their quality parameters, to serve as a tool to enable efficient trading of this biofuel and to achieve good understanding between seller and customer as well as to facilitate communication with equipment manufacturers.

For this purpose, a total of 176 olive stone samples from 71 different places have been collected and analyzed in this research. Data obtained have been used to develop two quality systems. On the one hand, a classification of olive stone quality parameters has been developed and data are described in a similar way to standardized European quality label for wood pellets. On the other hand, a procedure to calculate a quality index has been designed. Both quality systems have obtained similar results. However, the first one has shown to be more strict. In conclusion, both of them could be used in order to provide a quality classification for olive stone residues.

1. Introduction

Currently, biomass represents approximately 14% of the world's final energy consumption [1]. In developing countries, biomass can represent from 35 to 90% of the total energy supply, but in industrialized countries, biomass only represents from 9 to 14% of total energy provision [2]. However, a great energetic potential derived from biomass sources is available in industrialized countries. Given the fact that the structural reorientation of the energy system requires a repositioning in terms of a better exploitation of the local energy source [3], it is necessary to carry through quality analysis of typical raw materials of each region, since they could become the main energy source of the areas where they are generated. With respect to electric energy, biomass can be stored and energy system is easily managed.

In Mediterranean areas of European Southwest, agroindustrial activities are very important and a great amount of biomass is produced. Specifically in Spain, a biomass market with particular characteristics that differ from the rest of Europe is constituted. Likewise, in this region there is a large production of native solid biofuels such as those from olive industry in Andalusia (Southern Spanish region), which are very different from those derived from forestry activities.

Olive industry presents a high potential for solid biofuel production because of residues generated from olive groves and those by olive oil industries [4]. 25% of total Spanish residual biomass is produced by the olive sector and olive stone is among the most important since its production is over 450,000 tons/year [5]. 99% of olive stone residues generated are used in combustion processes to obtain thermal energy [6]. Energetic properties of this biofuel vary widely depending on whether it has been modified by industrial processes before consumption.

Olive stone residues aim at being consolidated in biofuels market and being commercialized through storage and distribution

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http://dx.doi.org/10.1016/j.renene.2013.12.009

companies thus guaranteeing biomass characteristics and quality parameters [7], although a lack of standardization of olive stone physicochemical properties is delaying the development of this market.

Biofuel characterization constitutes a substantial improvement in the valuation of this resource and permits a rational and controlled utilization of its energy potential. According to its quality parameters, olive stone could be managed as solid biofuel to obtain the most efficient energetic processes. In this context, there is a European quality label for wood pellets [8] but there is nothing similar for olive stone.

For these reasons, research developed is focused on providing unambiguous and clear classification principles for olive stone residues, to serve as a tool to enable efficient trading of this biofuel and to achieve good understanding between seller and customer as well as to facilitate communication with equipment manufacturers. This quality study is based on the use of olive stone residues for domestic and medium-scale heating appliances, in which sensitivity to the biofuel quality can cause major issues. Biofuel quality establishment in the market is difficult due to the large number of quality parameters available. Therefore, a simple quality index based on quality parameters studied, to evaluate easily and economically the biofuels would become an important tool.

For this purpose, two olive stone quality systems have been developed in this research. On the one hand, a classification of olive stone quality parameters has been built and data have been described in a similar way to the European quality label system for wood pellets [8]. On the other hand, a quality index has been designed with the scope of obtaining a score for olive stone residues, which becomes an easy and understandable tool for producers and customers.

2. Materials and methods

2.1. Raw material

A sampling plan has been designed to collect olive stone residues from different Andalusian industries, including olive stone supplied by olive-oil mills (*almazaras*) and distribution companies. In this research, a total of 176 olive stone samples from 71 different places, where the main Spanish varieties of olives (*Picual, Albequina, Picuda* and *Hojiblanca*) are found, have been handled and analyzed (after a grinding-up to 0.25 mm). Samples have been collected from Andalusian provinces such as Jaén, Córdoba, Seville, Malaga, and Granada, where about 82.5% of Spanish olive stone is generated [9]. In addition, several samples were collected from other places such as Extremadura, Cataluña, Morocco and Tunisia. This sampling plan was performed in order to obtain the highest quality parameters variability, being considered the widest geographical and climate diversity and it includes 96 samples collected from olive oil factories and 80 samples collected from distribution companies.

Olive stone originated from table olive has not been taken into account in this research because the industrial production is negligible in relation to olive oil industry [10].

2.2. Determination of quality parameters and equipment

Quality parameters have been determined by official methods established by the European Standard Technology Committee [11]. In Spain, the adaptation of this methodology is established by the Spanish Association for Standardization and Certification (AENOR). Standards and used measurement equipment are shown in Table 1.

Samples have been characterized by content in dry weight. Parameters have been determined in 176 olive stone samples except microelements, oil content, particle size and ash-melting behavior, which have been analyzed in 10 olive stone samples since methodology is complex and expensive. These 10 olive stone samples have been particularly chosen with the objective of covering a wide range of data variability, basing on differences of chlorine, sulfur, pulp and ash content in all the samples.

Moisture content experimental determination consists of a sample weight difference measured in a stove at 105 °C for a time not superior to 24 h. Results are expressed as mass loss percentage.

In order to obtain the ash content, samples are introduced in a furnace at 550 ± 10 °C during 4 h. The result is the difference before and after determination of the sample weight. Ash content is expressed as percentage in dry weight basis.

In the determination of the volatile matter, samples are introduced in a furnace at 900 ± 10 °C during 7 min. The result is the difference before and after determination of the sample weight and it is expressed as percentage in dry weight basis.

Higher heating value (HHV) was determined using an automatic isoperibol Parr 6300 calorimeter. Results are expressed as MJ/kg in dry weight basis. Lower heating value (LHV) has been calculated based on ultimate analysis and HHV experimental values [12].

In order to determine carbon (C), hydrogen (H) and nitrogen (N) contents, a known mass of sample is burnt in oxygen under conditions to convert it into ash and gaseous products of combustion analyzed by gas analysis instrument.

Table 1
Biomass quality parameters standards followed and measurement equipment used. Measurement error is shown as the average standard deviation of analyzed olive stone samples.

Parameter	Standard	Measurement equipment	Standard deviation
Moisture (%)	EN 14774-1	Drying oven memmert UFE 700	*
Ash (%)	EN 14775	Muffle furnace NABERTHERM LVT 15/11	0.02
Volatile matter (%)	EN 15148	Muffle furnace NABERTHERM LVT 15/11	0.33
Gross calorific value (MJ/kg)	EN 14918	Calorimeter Parr 6300	0.02
Net calorific value (MJ/kg)	EN 14918	Calorimeter Parr 6300	0.02
Total carbon (%)	EN 15104	Analyzer LECO TruSpec CHN 620-100-400	0.12
Total hydrogen (%)	EN 15104	Analyzer LECO TruSpec CHN 620-100-400	0.03
Total nitrogen (%)	EN 15104	Analyzer LECO TruSpec CHN 620-100-400	0.009
Total sulfur (%)	EN 15289	Analyzer LECO TruSpec S 630-100-700	0.002
Total chlorine (mg/kg)	EN 15289	Titrator Mettler Toledo G20	6.73
Bulk density (kg/m^3)	EN 15103	Standardized container	6.8
Minor elements (mg/kg)	EN 15297	ICP OES VARIAN 715-ES	*
Ash melting behavior (°C)	CEN/TS 15370-1	LECO AF 700 789-700-100	*
Oil content (%)	UNE 55030	Soxhlet extraction	0.02
Size particle (%)	EN 15149-2	Sieving machine Restch AS 200	*

*According to official standards, this parameter is not calculated.