DETERMINATION OF COMBUSTION CHARACTERISTIC OF OLIVE BAGASSE (PRINA) BY TGA

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Abstract

The evaluation of the generated wastes after production in different sectors is important for waste control and economy of the countries. Olive bagasse (prina) that arise after the production of olive oil has a high thermal value due to its high organic content. For this reason, the evaluability of prina as fuel is considered. In this study, the combustion characteristics of prina obtained from an olive oil plant in the Manisa-Soma region were investigated through thermogravimetric analysis. The TGA and DTGA curves were interpreted to evaluate the burning profile, reaction regions, peak temperatures, and ignition temperatures of the prina.

Keywords: *Olive bagasse, combustion characteristics, TGA, DTGA.*

1. INTRODUCTION

Energy has a great importance for the development of countries. Although most of the energy production is provided by fossil fuels, the limited availability of these resources requires the search for alternative new energy sources. Especially the evaluation of agricultural wastes in energy production shows that the energy dependency to imported fossil fuels and the amount of waste could be decreased in particular.

Mediterranean countries such as Tunisia, Spain, Portugal, Italy, Greece, Turkey, Syria and Morocco meet 90% of the world olive oil production (Zampounis, 2017). Olive production is concentrated in Mediterranean, Aegean and Marmara regions in Turkey (Fig. 1) (DG Cooperatives, 2018). While the olive production of Turkey was 2,1 million tons, the olive oil production was 263 thousand tons in 2017 (DG Cooperatives, 2018). Approximately 68% of the olive produced in Turkey are used in olive oil production.

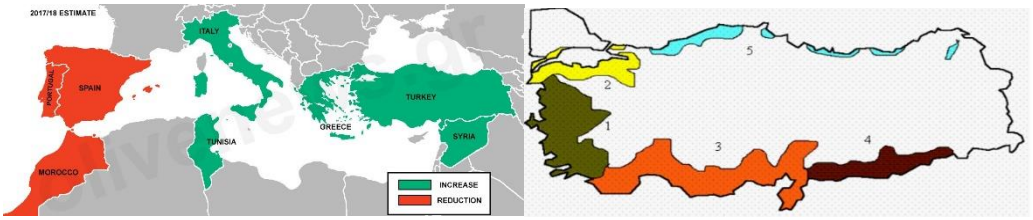

Figure 1. The olive oil production in the world (left) and Turkey (right) (Zampounis, 2017; DG Cooperatives, 2018)

In generally, the sediment formed after olive pressing consists olive (6-8%), water (20-33%), seeds and dough (59-74%) depending on olive oil extraction processes. After leaving the olive oil, the remaining solid part is called as prina (Gorel et al., 2003). While 35-45 kg prina emerges from 100 kg olive (Malkoc et al., 2006; Ocal, 2005; Baskan, 2010; Kurtulus, 2003), 60-70% of it is oil free prina (Kurtulus, 2004). Prina is used as fuel due to the containing of its 5-6% of oil and is also used as fertilizer and filler in agriculture (Gorel et al., 2003). In addition, the oil which obtained from olive pulp by using solvents can be utilized for several industries such as soap industry, sugar factories etc. (Keser and Bilal, 2010). Prina have a high thermal value due to the containing of oil and organic substances. For this reason, it is possible to use it as a fuel and therefore an energy source. So, it is important to determine the combustion characteristics of the prina. Oil free prina is also being used as fuel in Turkey (Akin, 2005).

Thermogravimetric analysis (TGA) is which is an effective method widely used for the quantitative determination of mass loss as a function of the gradual increase in temperature (Iordanidis, et al., 2001). At the same time, TGA is one of the most common techniques used to determine the combustion characteristics of materials and to investigate their kinetics. In this study, the combustion characteristics of olive bagasse (prina) obtained from an olive oil plant in the Manisa-Soma, region (Turkey) were investigated through thermogravimetric analysis. The TGA and DTGA curves were interpreted to evaluate the burning profile, reaction zones, peak temperatures, and ignition temperatures of the prina.

2. MATERIALS AND METHODS

2.1. Materials

Approximately 5 kg of prina received from the factory were kept in closed containers for protection of the original form. After the prina was dried at 105 °C, the proximate analyse was carried out and given in Table 1. As seen from the Table 1, prina had a high calorific value (LCV) depending on its high fixed carbon (FC) value. In addition the volatile matter (VM) was 58% with low ash content.

Table 1. Proximate Analyses of olive bagasse (prina).

Sample	Ash, (%)	VM, (%)	FC, (%)	LHV, (kcal/kg)
Prina	3.47	58	38.53	4744

The prina sample was prepared for the experiments by dividing into four different particle sizes such as -212, -212+106, -106+53 and -53 μm, in order to determine the thermal values and combustion characteristics.

2.2. Methods

The thermal value of prina was determined according to the ASTM D 5865-11a standard (ASTM D 5865-11a 2011). Calorimetric measurements were performed by using the LECO AC-350 model adiabatic oxygen bomb calorimeter (Fig. 1). Each measurement was repeated two times at least.

Approximately 1 g of dry sample was placed into the sample vessel to perform the calorimetric measurement, and then the combustion wire was contacted with the sample. The vessel was then placed into the high pressure combustion bomb. The combustion in the oxygen environment was carried out and the calorific value of the sample was calculated.

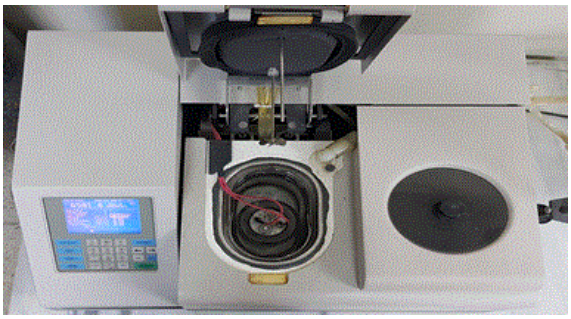

Figure 1. LECO Calorimeter device.

A PL (Polymer Laboratories) model TGA 1500 thermogravimetric analyser was used to determine the burning characteristics of prina (Fig. 2). Approximately 5 mg of sample was uniformly spread into the

platinum vessel of the device. The tests were carried out in a flow of 5 ml/min of air and at a linear heating rate of 10 °C/min, starting at ambient temperature and heating to 650-1000 °C.



Figure 2. Termogravimetric Analysis device.

3. RESULTS AND DISCUSSION

The TGA and DTGA curves of -212, -212+106, -106+53 and -53 μm of fractions of prina obtained from thermogravimetric analysis were given in Fig. 3.

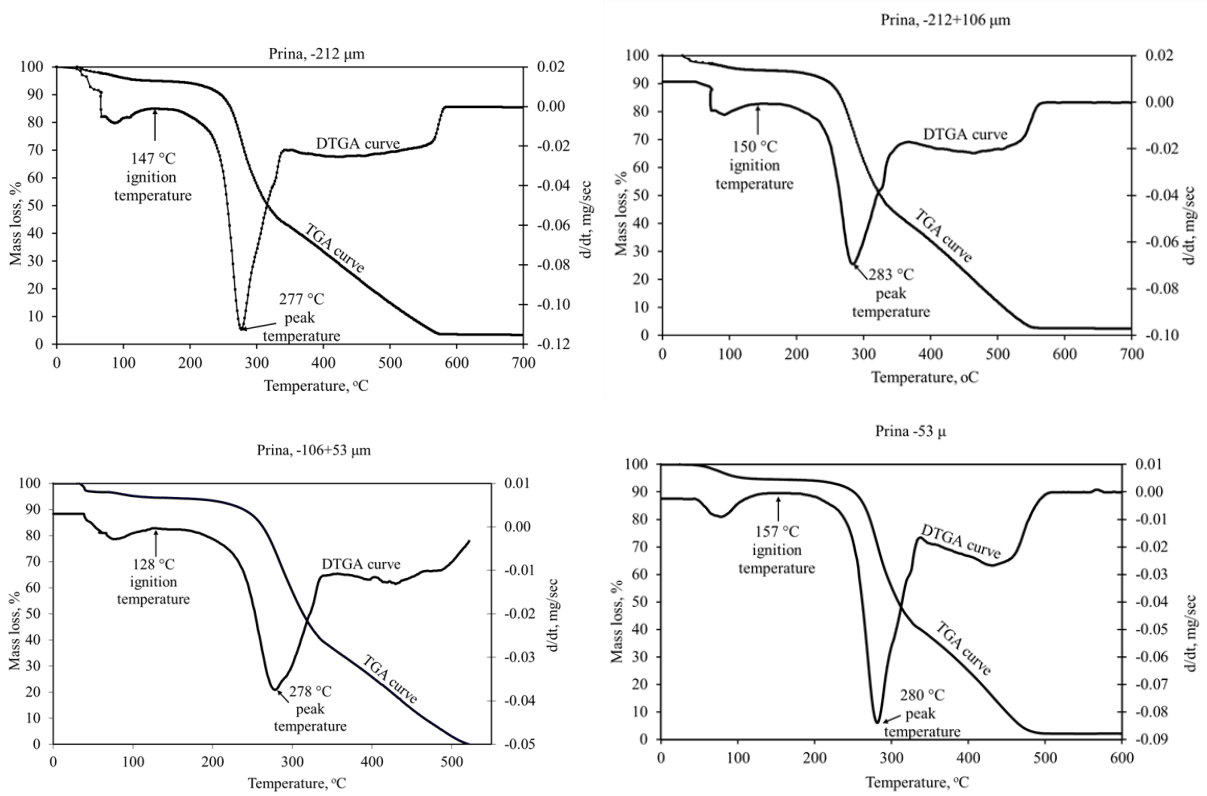

Figure 3. TG and DTG analysis curves of prina.

It could be seen from Fig.3 that the TG curves of all the fractions behaved in a similar manner. The mass loss had occurred in three different regions. Where the moisture removed at first region, volatile matters removed at second region. In addition, the oil and carbon content of prina also burned at the second region. At the region third, the prina was completely decomposed. It was observed that the first region

was at between 25-120 °C, the thermal decomposition took place at 220-560 °C (the second region), and the final combustion temperature was at 490-600 °C where the third region.

DTG analyses include the data obtained by taking the primary derivation of the mass loss over time. In other words, DTG curves show the change in the rate of mass loss with increasing temperature. In this study, the ignition temperatures and peak temperatures for prina samples were calculated according to Equation 1 given below.

$$\frac{(T_{final}-T_{inital})}{(t_{final}-t_{inital})} = \frac{dW}{dt} \quad (1)$$

Where; *T* is temperature (°C), *t* is time (min), *W* is weight of sample.

The ignition temperature and peak temperature can be determined from the DTG curves. While the first peak indicates the ignition temperature, the second peak represents the peak temperature in the burning profile of DTG curves of prina. As seen from the Fig. 3, the ignition temperature was varied between 128-157 °C, the peak temperature was varied between 277-283 °C and the final combustion temperature was varied between 510-600 °C. Similar results were found in the literature. It is known that the ignition temperature can be range from 200 to 250°C regardless of the type of the biomass (Toptas, et al., 2015; Vamvuka and Sfakiotakis, 2011). The final combustion usually takes place at between 500 to 600 °C (Vamvuka and Sfakiotakis, 2011; Yuzbasi and Selcuk, 2011) and less frequently at 800 ° C (Varol et al., 2010) for this type of biomass. Magalhães et al. (2017) reported from their thermogravimetric analysis results of the olive bagasse sample that the ignition temperature, the peak temperature and the final combustion temperature were realized at 150 °C, between 250-260 °C and between 500-700 °C, respectively. Similarly, the peak temperatures of some kind of olive bagasse were varied at 150 to 230°C, the ignition temperatures were also varied at between 300-436 °C ant the final combustion temperatures were 500-600 °C (Guizani et al., 2016; Gil et al., 2010 and Kastanaki et al., 2002).

The combustion characteristics of prina were given in Table 2. As seen from Table 2, the total mass loss of prina was determined as to be between 97-100%. This means that prina sample was nearly burned completely at that temperatures. In addition, the LHV values of sample were not changed much with particle size. Therefore, the particle size of sample was not important when it was under the 212 µm.

Table 2. Combustion characteristics of prina.

Particle size, µm	Combustion characteristics			
	Ignition temperature, °C	Peak temperature, °C	Total mass loss, %	LHV, (kcal/kg)
-212	147	277	97	4744
-212+106	150	283	98	4623
-106+53	128	278	100	4530
-53	157	280	99	4841

4. CONCLUSIONS

The combustion characteristics of prina sample for four particle size as -212, 212 + 106, -106 + 53 and -53 µm was investigated in this study.

The obtained TG curves for all fractions were showed similar trend.

Three reaction regions were observed from the DTG profiles of sample.

The ignition temperature was varied between 128-157 °C, the peak temperature was varied between 277-283 °C and the final combustion temperature was varied between 510-600 °C.

The total mass losses of prina were also varied between 97-100%.

The LHV of sample was varied between 4530-4841 kcal/kg and not changed much with particle size.

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