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Original article

Experimental Study of Thermal Pyrolysis of Avocado Seed for Liquid Fuel Production

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Abstract

Bio-waste which is available in large quantities worldwide is rich in biodegradable organic matter. By utilizing from bio-waste as feedstocks to attain valuable bio-based products, resource and waste problems will be solved as being “double green”. The bio-waste utilization aids decrease pollution while providing renewable energy and bio-based chemicals for the upcoming utilizations. Consequently, bio-waste resource utilization has involved growing attention in scientific and industrial societies.

The characteristic of avocado seed as a bio-waste was analysed using elemental analysis resulted as 39.89% C, 5.43% H, 0.43% N, 45.2% O content. The higher heating value was calculated using Dulong Formula as 13.70 MJ/kg. The raw milled bio-waste was characterized by FT-IR containing the wavenumbers in the range of 4000-400 cm-1. The spectra bands for bio-waste demonstrated characteristic peaks of cellulose, hemicellulose and lignin. The mean moisture and ash contents of the “as-received” avocado seeds employed in this study were 6.54 wt% and 2.42 wt.%, respectively. Pyrolysis of avocado seed was carried out in a Heinze reactor at 500°C with a heating rate of 10°C/min and retention time of 20 min. The pyrolysis experiment yielded the liquid product (32%), solid product “char” (34%) and non-condensable gas (34%) with biomass conversion of 67%. Based on the results, it was confirmed that avocado seed can be utilized as a potential bio-waste according to pyrolysis results but liquid properties as a bio-fuel oil and solid product char properties as an activated carbon should be evaluated in detail.

Keywords: Avocado seed, biomass, bio-waste, pyrolysis, waste management

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INTRODUCTION

Bio-wastes are accepted as one of the main pollution issues due to landfills and the emission of greenhouse gases since domestic waste. As a result, the requirement to utilize these wastes in many application areas are not only a necessity but also a vital obligation (Gaur et.al., 2020). While some researchers were able to develop an environment-friendly aspect in order to achieve high-value chemicals, some of them were used to attain bio-oils to utilize as fuels and activated carbons to utilize for adsorption. Some of the materials utilized as bio-waste in the literature are tomato paste waste (Özbay et al., 2018), banana peel (Özbay et al, 2019), sugar beet pulp (Yarbay-Şahin et al, 2014), sunflower waste (Yargıç et al. 2013).

The avocado (*Persea Americana*) is an extremely nutritious and commonly disbursed subtropical fruit high in unsaturated fats and vitamins (Sánchez et al., 2017). While worldwide avocado production was $2.71x10^6$ metric tonnes in 2001, the number was increased by 42.8% to about 3.87x 106 metric tonnes in 2010 and 6.41x 10^6 metric tonnes in 2018. Among the producers, Mexico was noticed as the leading avocado producer country according to the records as 34% ($2.18x10^6$ metric tonnes) of the global avocados in 2018/2019. Mexico was followed by Indonesia (410.09 x 10^3 metric tonnes), Colombia (403.18 x 10^3 metric tonnes) and Peru (338 x 10^3 metric tonnes) (Juma, 2020). The avocado market is increasing rapidly in Europe as well, mostly in countries of the Mediterranean basin such as Spain, France, Italy and Greece (Sánchez et al., 2017).

Its rich nutritional content and health benefits favours the avocado fruit as an important trade commodity globally. Avocado fruits are commonly utilised as food, especially used as plain fruit, in salads or as juice (Juma 2020). After utilizing the fruit, its organic waste involving mainly of seeds and husks mixed with a small proportion of pulp. Hereafter, this waste is in most cases simply disarmed by landfilling and composted in order to use in a fertilizer and soil conditioner (Sánchez et al., 2017).

To the best of authors knowledge, only a few studies have been conducted in order to deal with the energy valorisation of avocado seeds into biofuels such as biodiesel and bioethanol. The potential of avocado seeds for pyrolysis is also very rare (Sánchez et al., 2017, Durak and Aysu, 2015).

The aim of this paper is to assess the fuel potential of avocado seeds and to examine the pyrolysis as one of the thermochemical approaches using a Heinze reactor. Before using in pyrolysis, the bio-waste was characterized in terms of elemental and FT-IR analysis. Product yields calculated from pyrolysis using formulas has been discussed. The present investigation demonstrates the relationship between the chemical character of avocado seed on its pyrolysis yields.

MATERIALS and METHODS

Bio-waste Feedstock

The seeds of avocado grown in Alanya (Antalya/Turkey) were separated and dried and ground in the "Armfield FT-7A" mill, ready for both elemental analysis and pyrolysis.

Bio-waste was sieved to attain average particle size before pyrolysis experiments. ASTM E 897-82 and ASTM D 1102-84 standard test methods were used to for volatile matter and ash determination, respectively. The weight fraction of moisture content was obtained in Sartorius MA 150 moisture analyser.

The Pyrolysis Experiments

Air-dried biomass in amount of 15 g was put into the reactor which was heated by an electric furnace and the temperature was increased to a final temperature of 500°C with a heating rate of 10 °C/min and holding time of 20 min. The liquid product involving both aqueous and oil phases were separated by using a separating funnel and then weighed. After removing the solid char from the reactor, the gas yield was able to calculate by the difference (Özbay et al., 2018). The equations used to calculate the conversion, liquid, solid and gas yields can be found elsewhere (Durak and Aysu, 2015). Pyrolysis experiments were performed at least in duplicate and the values reported signify the average of these determinations.

Characterization Methods

The elemental analysis applied to determine the amount of carbon, hydrogen, oxygen nitrogen and sulphur contained in the bio-waste was carried out on Leco CHN628, S628 device. The carbon, hydrogen, oxygen and sulphur contents of the biomass determined were calculated using the higher heat value (HHV) of the Dulong’s formula as reported by Harker and Backhurst gave in Equation 1 (Harker and Backhurst, 1981).

$$Higher\ Heating\ Value\ (kJ/kg) = 338{,}2C + 1442{,}8\left(H - \frac{O}{8}\right) + 94{,}2S \qquad \text{(Eqn. 1)}$$

FT-IR analysis was done to specify the functional group of bio-waste using Agilent Cary 630 spectrometer Instrument.

RESULTS and DISCUSSION

Elemental analysis results of air-dried, ground, sieved avocado seeds are given in Table 1. Despite its high oxygen content, it can be seen as a very promising biomass source with its low nitrogen and sulphur content. The mean moisture and ash contents of the avocado seeds employed in this study were 6.54 wt % and 2.42 wt %, respectively.

Table 1. Ultimate analysis (wt.%) of the avocado seed.

Ultimate analysis	
Carbon (wt.%)	39.89
Hydrogen (wt.%)	5.43
Nitrogen (wt.%)	0.43
Oxygen (wt.%) (from difference)	45.2
Sulphur	0.55
H/C	1.62
O/C	0.85
Higher heating value (MJ/kg)	13.70

The FT-IR spectrum of the avocado seed is given in Figure 1. When the FT-IR spectrum was examined, a wide and widespread –OH peak was observed at 3250 cm^{-1}. This peak highlights the presence of alcohol, phenol or carboxylic acids. The peaks are seen in 2910-2850 cm^{-1} and 1500-1380 cm^{-1} indicate the presence of aliphatic structures with asymmetrical and symmetrical C-H vibrations. The bands at 2100-2000 cm^{-1} indicate the C≡N stress vibrations and belong to the characteristic adsorption of 1240 cm^{-1} C-N. The peak seen at 1900 cm^{-1} is C = C = C stretching peak. Severe peaks seen around 1750-1600 cm^{-1} are caused by olefinic C = C vibrations and C = O vibrations in aromatic structures. Peaks showing the aromatic C-H structure in the range of 1000 cm^{-1} and 600 cm^{-1} were also recorded.

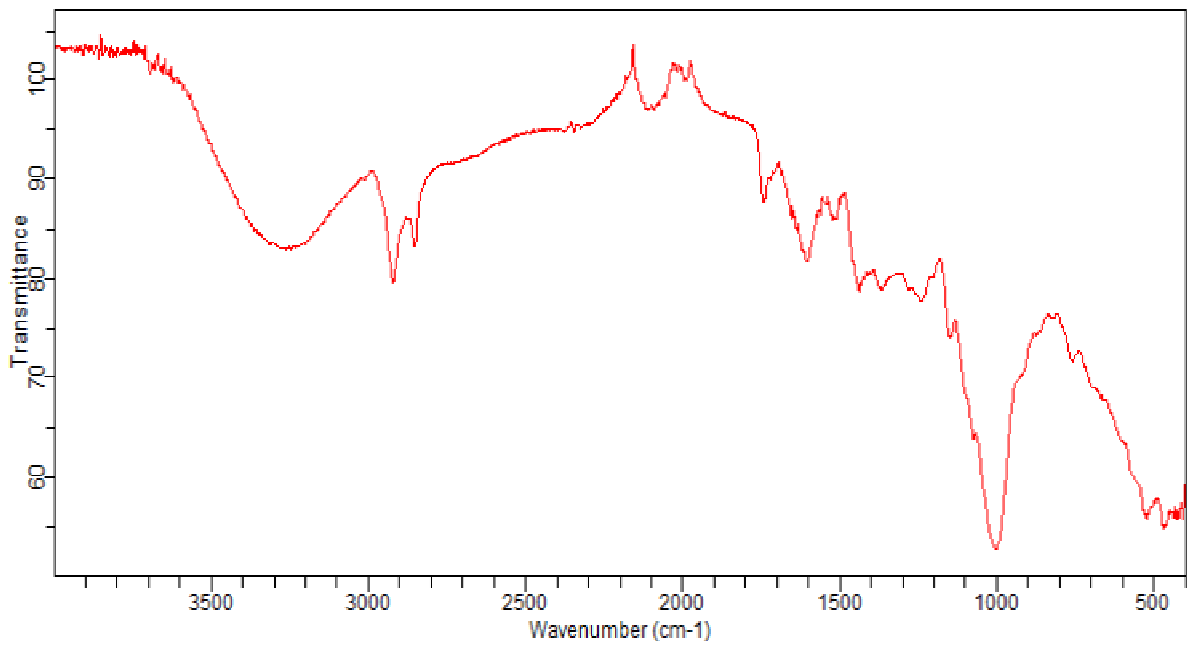

Figure 1. FT-IR spectrum of avocado seed.

Table 2 displays the product yields of avocado seed pyrolysis at fixed conditions. From Table 2, it can be stated that the solid fraction represents 33.50 wt % of the original mass, the condensable "liquid" product 32.86 wt% and the gaseous fraction 33.63 wt %. The conversion of the avocado seed into gaseous and liquid products was calculated as 67.08 wt %.

Table 2. Pyrolysis and conversion yields of the avocado seed.

Conversion (%)	Liquid product (%)	Gaseous product (%)	Solid product (%)
67.08	32.86	33.63	33.50

Results which are parallel to the current study were recorded in the previous studies on the avocado seed pyrolysis. In a study conducted by Durak et al. (2005), thermal and catalytic pyrolysis of avocado seeds was carried in a fixed-bed tubular reactor at temperatures varying 400 to 600 °C, with heating rates of 50 °C/min. It was found that both temperature and catalysts were determined to be the main factors affecting the conversion of avocado seeds. The highest liquid yield (37.5 wt %) including water was attained using 10 % KOH catalyst at 600 °C (Durak and Aysu, 2015).

In another study, investigators dealt with especially torrefaction and carbonization of avocado seeds in order to layout the chemical, physical and fuel properties of the solids and liquids obtained in the temperature range between 150 and 900 °C. The transformation of the avocado seeds into different fractions was evaluated as 25.1 wt % solid, 55.9 wt % liquid and 19 wt % gas product at 500 °C. As a result, the study underlines that thermal processing can be evaluated in order to reduce the volatile fraction of this biomass, obtaining an improved solid bio-fuel and a valuable liquid with for further energy uses (Juma, 2020).

Conclusion

The aim of this paper was to evaluate the characterization of avocado seeds and to examine the pyrolysis of this bio-waste using a Heinze reactor. Pyrolysis of avocado seed implemented at 500°C with a heating rate of 10 °C/min and retention time of 20 min resulted liquid product (32%), solid product "char" (34 %) and gaseous product (34 %) with biomass conversion of 67 %. The results indicated that pyrolysis of avocado seed can be evaluated as a hopeful process for achieving activated carbon, bio-fuel and valuable chemicals production. After evaluating its characteristic in detail, bio-oil obtained from avocado seed pyrolysis liquid product can be used in many application areas.

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