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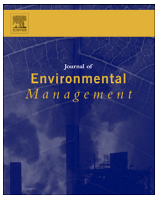

Research article

Production and characterization of chars from cherry pulp via pyrolysis

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ABSTRACT

Pyrolysis is an eco-friendly process to achieve valuable products like bio-oil, char and gases. In the last decades, biochar production from pyrolysis of a wide variety of industrial and agricultural wastes become popular, which can be utilized as adsorbent instead of the expensive activated carbons. In this study, cherry pulp was pyrolyzed in a fixed bed tubular reactor at five different temperatures (400, 500,550, 600 and 700 °C) and three different heating rates (10, 100 and 200 °C/min) to obtain biochar. Proximate, ultimate, nitrogen adsorption/desorption isotherms, scanning electron microscopy, thermogravimetric analysis, x-ray fluorescence, x-ray diffraction, and Fourier transform infrared spectroscopy were performed on cherry pulp and its chars to examine the chemical alterations after the pyrolysis process. Biochar yields were decreased with increasing pyrolysis temperature and heating rate, based on experimental results. Porous biochars are carbon rich and includes high potassium content. The aromaticity of biochars increased and O/C mass ratio reduced with an increase in the pyrolysis temperature as a result of the development of compact aromatic structure in char. Pyrolysis provides a promising conversion procedure for the production of high energy density char which has promising applications in existing coal-fired boilers without any upgrading.

1. Introduction

Environmental impacts of greenhouse gases, the dependence on fossil fuels and increasing energy demand are common concerns. According to literature, world demand for energy in 2050 will be doubled compared to 2000. The coal reserves will be depleted at 2112. Therefore, renewable energy appears to be the only option to replace fossil energy sources. Agricultural wastes such as biomass residues are increasingly being recognized as valuable renewable feedstocks due to their carbon-rich composition around the world. The world's biomass production is approximately 985 million tons per year. It currently contributes about 10.0% or 50.0 exajoule, EJ of the total primary energy supply. Additionally, a total of 370.0 TWh of electricity was produced from biomass in 2012, which corresponds to 1.5% of world electricity generation and 3.5% of road transport fuel is provided by biofuels today. The European Union (EU) has set a 2020 goal for substituting 10% of traditional fuels by biofuels (Colantoni et al., 2016; Long et al., 2013).

The so-called "second generation" technologies for the production of fuels enable the use of a wide range of non-food cellulosic biomass feedstocks. Cellulosic biomass normally consists of cellulose, hemicellulose and lignin in the proportions 35–50%, 15–25% and 15–30% respectively. It can be thermochemically transformed via direct combustion, gasification, co-gasification with coal or pyrolysis. Pyrolysis is an appealing way of generating biofuels in the form of bio-oil, char and biogas, and is quite efficient compared with the other methods. In pyrolysis, the biomass is heated without oxygen. It is decomposed into a solid residue (char), bio-oil, and gas. The char is mostly defined as porous carbonaceous solid by product. However, while the final products typically consist of char which is 15% of the total, accounting 25% of the energy of the biomass feedstock; it may, therefore, have potential as a fuel when burned under optimum combustion conditions (Li et al., 2016; López et al., 2013).

Biochar is a value-added product which can be used for several purposes. The solid biochar, similar to fossil coal, is a useful product that can be used as biofuel. It is highly carbonaceous with a high energy content compared to high rank coals. Moreover, these fuels sequester carbon. Biochar also has a large microscopic surface area due to the micro-pores developed during pyrolysis; therefore, biochar can be employed for the filtration and adsorption of

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Table 1
Properties of CP.

	wt.%		wt.%		ppm
Moisture[c]	6.42	C[a]	50.80	Mg	0.88
Ash[b]	1.86	H[a]	6.79	Al	0.1
Volatile matter[b]	72.02	N[a]	2.67	Si	0.14
Fixed carbon[b]	19.70	O[a]	39.66	P	6.15
Cellulose[c]	24.77	H/C	1.60	K	27.19
Acid-insoluble Lignin[b]	49.03	O/C	0.58	Ca	22.68
Oil[c]	6.15	Empirical formula	$CH_{1.60}$ $N_{0,045}O_{0.58}$	Fe	0.49
Alcohol-benzene solubles[b] (extractives)	6.42	Higher Heating value ($MJkg^{-1}$)	19.82		
Raw Protein[a]	8.97	Bulk Density[c] (kg/m^3)	732.2		

[a] Dry-ash-free basis.
[b] Dry basis.
[c] As received.

pollutants. Such features of biochar can be further enhanced by physical or chemical activation, of which the final product becomes adsorbent, which is also referred to as a substitute for activated carbon. The incorporation of biochar into the soil is a critical strategy for sequestering atmospheric carbon dioxide and improving soil quality. Mixing biochar with the soil could increase the soil's nutrient retention capacity, water holding capacity, soil pH value, and crop yield. These increases are possible as the biochar contains inorganic components (for example, Ca, K, Mg, P, and so on.) which act as a liming agent and supplies plants with available nutrients, thus, decreasing the bio-availability of heavy metals and organic contamination (Wang et al., 2014).

Turkey has always been one of the major agricultural countries of the world. Total bioenergy potential of Turkey was estimated as average 32.0 Mtoe (million tonnes of oil equivalent) per annum (Toklu, 2017). It is very advantageous to use biomass as an energy source in Turkey. Different kind of fruits can be produced in this country due to its various climate conditions and geological position (Eriş and Barut, 2000). Cherry could be one of the candidates owing to the following reasons: Cherry (*Prunus cerasus* L.) is a seedy fruit which belongs to rosaceae family prunus class. It is rich in minerals and especially suitable to use as fruit juice according to its high juice yield (up to 70–75%) and acidity nature (3%) (Barett et al., 2005). Cherry consists of 60.4–71.4% meaty part, 13.5–18.1% shell and 5.5–7.9% stone. Cherry stone is split up with a mechanic stone separator before processing as conserve as same as fruit juice. The total world production of cherry is about 955,696 tonnes. The leading countries in cherry production were Russian, Turkey, Ukraine, Poland and USA. While Russian was in the first place with the production of 250,000 tons, Turkey and Ukraine were following with 180,917 and 134,600 tonnes, respectively. As reported by National Agricultural Statics Service in Turkey, cherry consumption up to 90% was occurred as fruit juice, jam and conserve (USDA, 2016).

Agrafioti et al. (2013) studied the evolvement of pyrolysis in a muffle furnace and found that the char yield was reduced remarkably, from 62.5 to 27.3, as the temperature increased from 300 °C to 500 °C at 30 min residence time. Huff et al. (2014) investigated biochar production from pinewood, peanut shell, and bamboo biomass by slow pyrolysis over a temperature range of 300, 400 and 500. These biochars were characterized by FT-IR, cation exchange capacity (CEC) assay, methylene blue adsorption, as well as proximate and elemental analysis. They reported that there is an apparent trend of increasing aromaticity of the pyrolysis biochars when produced at higher temperatures and the possibility of the use of these biochars for the potential removal of certain organic molecules such as dyes in water. Colantoni et al. (2016) noted that the biochars produced from pelletized grape vine and sunflower husk agricultural residues could be used as substituted for non-renewable solid fuels in energy production. The biochars have a positive impact on soil nutrient characteristics due to the important contents of phosphorous and potassium. López et al. (2013) obtained chars by pyrolysis waste wood samples. The higher heating values of the chars were relatively high (31–35 MJ kg^{-1}) and comparable to that of a semi-anthracite or medium-volatile bituminous coal. A modified updraft fixed bed gasifier with embedded combustor is successfully applied to a Brazilian beehive kiln for biomass char production in the another study (Lin, 2006). The experimental results showed the current design is capable of producing a higher carbonization temperature, potential to significantly increase the biomass char yield and lower the cycle time. According to Lohri et al. (2016), produced char from urban solid bio-waste in low-cost pyrolysis system with proper design and operational conditions is used as a raw material for fueling. Low-tech retorts can be a financially viable option to support sustainable char production from biowaste carbonization, to improve energy efficiency, reduce air pollution and guarantee safe operation. Household biowastes have been thermally processed in a bench scale reactor by means high temperature pyrolysis by Vakalis et al. (2016). The thermochemical properties of the feedstock and products were analyzed by means of Simultaneous Thermal Analysis (STA), Ultimate and Proximate analysis and Attenuated Total Reflectance (ATR). The analysis of the products showed that high temperature pyrolysis produces a graphite like material with relatively high yield.

There are many studies related to biochar production from waste biomass in the literature. Duman et al. (2011) investigated pyrolysis of cherry seed and seed shell which is focused on biooil production. However, until recently, there is no literature on the utilization of cherry pulp (CP) to obtain biochar. In this study, pyrolysis experiments of cherry pulp were carried out in a fixed reactor to investigate the effects of pyrolysis temperature and heating rate on product yields and the physical and chemical properties of char. Chars produced via pyrolysis was characterized by complementary analytical techniques to evaluate the potential use of them. The elemental composition, content, functional groups, BET surface area and surface morphology of the chars were determined and a comparison between raw material and chars are done.

2. Materials and methods

2.1. Biomass sample

Cherry pulp was provided by a juice factory in Bursa/Turkey. Air dried biomass samples were ground and screened to give fractions of $D_p > 1.8$ mm, $1.8 > D_p > 0.85$ mm, $0.85 > D_p > 0.425$ mm, and $D_p > 0.425$ mm. Mean particle size was specified as 1.18 mm and

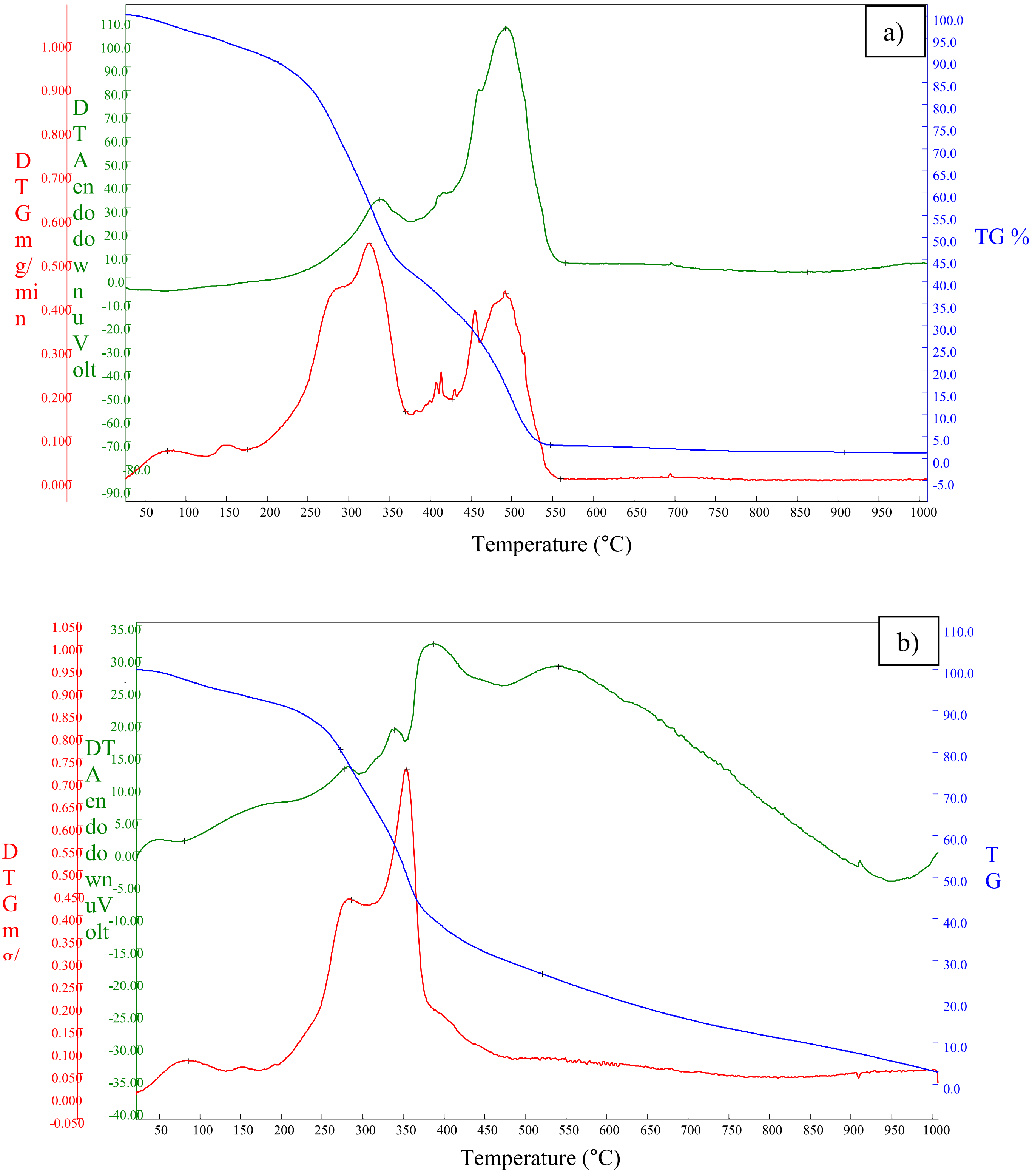

Fig. 1. TGA, DTG and DTA curves of cherry pulp under (a) nitrogen atmosphere, and (b) under air atmosphere.

was used for pyrolysis and individual characterization experiments.

2.2. *Pyrolysis experiments*

The pyrolysis experiments were carried out under nitrogen atmospheres using laboratory scale reactor described elsewhere (Uzun and Sarıoğlu, 2009). The reactor was heated directly by an AC electricity; for that reason, there was no furnace. This enables rapid heating and cooling. Heating rate and pyrolysis temperature were controlled with a PID (Proportional–Integral–Derivative)

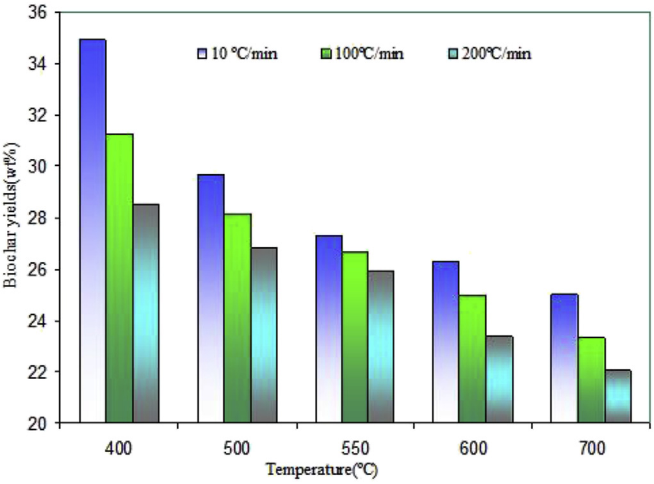

Fig. 2. Pyrolysis char yields obtained at heating rates 10 °C/min, 100 °C/min and 200 °C/min.

controller in the experiments. A rotameter was used to control the nitrogen flow rate better before entering into the reactor. Temperature measurements were acquired from the bed by the thermocouple in the middle of the reactor to control the reactor temperature and were followed from the control panel. The experiments were carried out under atmospheric pressure at five different temperatures (400, 500, 550, 600 and 700 °C) and three different heating rates (10, 100 and 200 °C/min). All the yields were expressed on a dry and ash-free basis, and their values were calculated as the average of at least three parallel experiments error less than ±0.5%.

2.3. Analysis of biomass and char

The proximate analysis of raw biomass and char was based on the ASTM standards (moisture content: ASTM E871-82, ash: ASTM D1102-84, volatile matter: ASTM E872-82 and fixed carbon is calculated by the difference). The ultimate analysis was achieved in an elemental analyzer (Leco CHN628, S628). The heating values are quite critical thermal properties for the design and the assessment

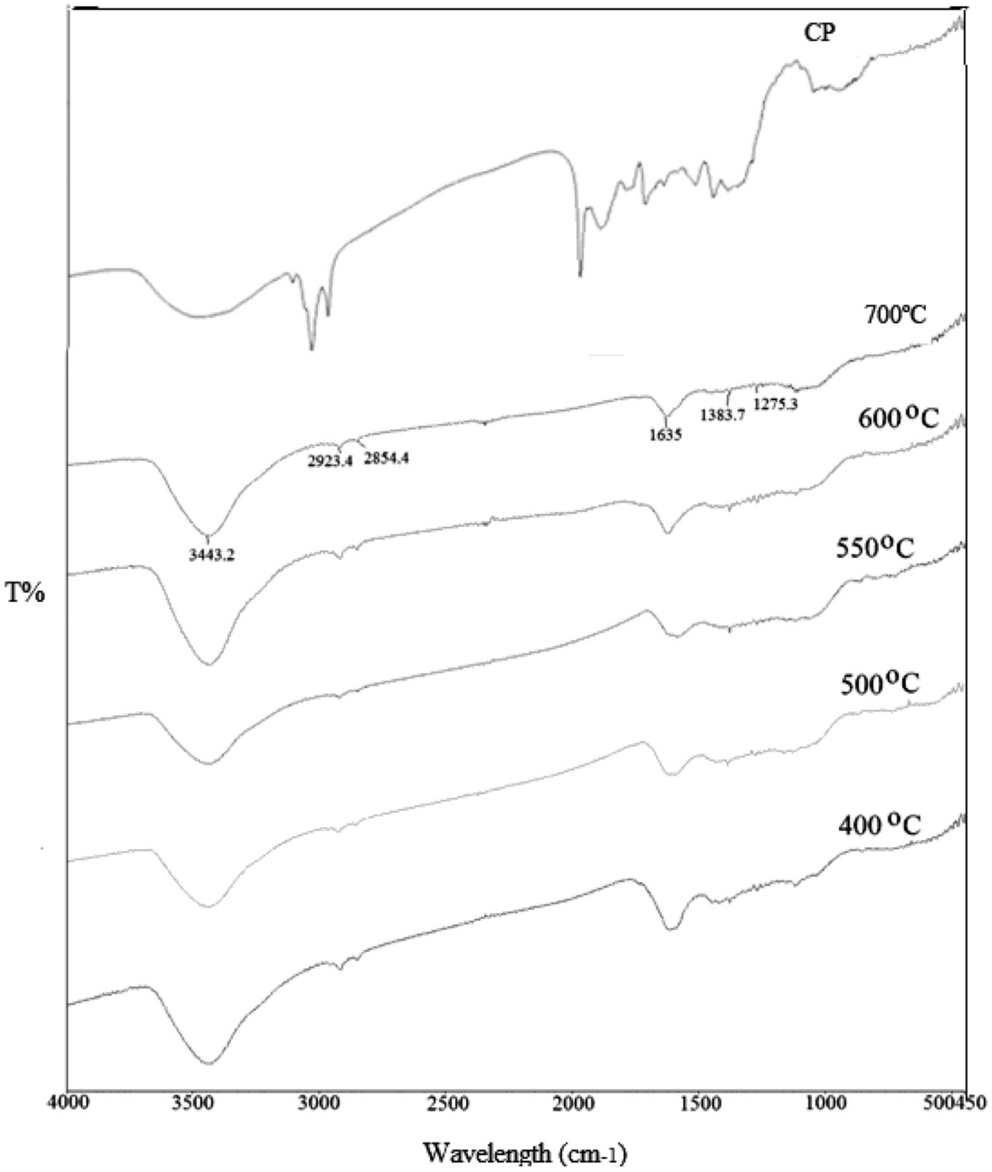

Fig. 3. FT-IR spectrum of raw material and chars obtained at different temperatures.

Table 2
The results of elemental analysis of chars.

	400 °C	500 °C	550 °C	600 °C	700 °C
Heating rate 10 °C/min					
C(wt.%)	67.62	76.59	73.49	85.67	87.88
H(wt.%)	3.93	2.68	3.60	3.98	3.72
N(wt.%)	4.92	4.50	5.44	5.15	5.47
O[a](wt.%)	23.53	16.23	17.47	5.20	2.93
H/C(wt.%)	0.81	0.42	0.58	0.55	0.50
O/C(wt.%)	0.44	0.16	0.18	0.04	0.02
HHV(Mjkg^{-1})[b]	24.30	26.84	26.90	33.78	34.56
Heating rate 100 °C/min					
C(wt.%)	69.68	75.54	73.56	71.67	73.19
H(wt.%)	3.24	2.32	3.89	4.58	4.52
N(wt.%)	4.47	5.77	6.83	6.86	5.01
O[a](wt.%)	22.61	16.37	15.72	16.89	17.28
H/C(wt.%)	0.55	0.37	0.63	0.76	0.74
O/C(wt.%)	0.24	0.16	0.16	0.18	0.18
HHV(Mjkg^{-1})[b]	24.16	25.94	27.66	27.80	28.16
Heating rate 200 °C/min					
C(wt.%)	67.70	69.66	75.52	79.34	75.07
H(wt.%)	3.99	4.82	3.52	2.68	4.16
N(wt.%)	4.28	6.53	6.45	5.24	7.21
O[a](wt.%)	24.03	18.99	14.51	12.74	13.56
H/C(wt.%)	0.70	0.82	0.55	0.40	0.66
O/C(wt.%)	0.27	0.20	0.14	0.12	0.14
HHV(Mjkg^{-1})[b]	24.31	27.09	28.00	28.40	28.94

[a] By difference.
[b] Calculated from Dulong Formula.

of thermal conversion systems. Higher Heating Values (HHV) were determined employing the Dulong formula as:

$$Q_{HHV}\ (\mathrm{Mj/kg}) = 33.83C + 144.3(H\text{- }O/8) \qquad (1)$$

where C, H, O represents the mass fractions of carbon, hydrogen, and oxygen respectively (Probstein and Hicks, 1982).

Thermogravimetric Analysis (TGA) was performed for the biomass sample and char, for a detailed analysis of the weight loss characteristics during pyrolysis. For about 10 mg of fine powders, a TGA analyzer (Setaram, Labsys evo) was used to measure the sample weight, while being heated from room temperature to 1000 °C with a heating rate of 10 °C/min, under a nitrogen and air (20.8% O_2/N_2 bal.) atmosphere (50 ml/min). The recorded weight loss history was normalized for the initial weight, and its rate was calculated.

Surface areas and pore volumes of the chars were determined by the application of the Brunauer–Emmett–Teller (BET) and t-plot analysis software available with an instrument (Micromeritics Asap 2020). Surface morphology of the samples was validated utilizing the Scanning Electron Microscope (SEM) Zeiss Supra 40 VP.

The obtained crystal structures of chars were examined by a diffractometer (PANanalytical X'Pert PRO). FT-IR spectra of samples were recorded using Perkin Elmer Frontier FT-IR LR64912C to gain more information on the chemical structure of the samples in the infrared region 4000–400 cm^{-1}, by preparing KBr pellets. XRF analysis of char was obtained with a Panalytical axios.

3. Results and discussion

3.1. Biomass characterization

Cherry pulp was used as feedstock in pyrolysis experiments. It was provided by a juice factory in Bursa, Turkey and used as received. The proximate, ultimate and component analysis of cherry pulp (CP) are given in Table 1. It shows that CP was richer in lignin (49.03%) than cellulose (24.77%). The holocellulose (sum of cellulose and hemi-cellulose) content was found as 42.69%. The chemical composition and higher heating value (HHV) value of the CP were within the expected range for wood biomass, with high volatile matter contents and low ash percentages (Telmo et al., 2010). The H/C and O/C ratios were, around 1.60 and 0.58, respectively. The HHVs for the CP were 19.82 MJ/kg. Similar biomass HHVs have been previously reported (Colantoni et al., 2016).

3.2. Thermogravimetric analysis results

The thermal degradation characteristics, thermogravimetric (TG) and differential thermogravimetric (DTG) curves of the CP are shown in Fig. 1a and b in nitrogen and air ambiences. The degradation behaviors of the biomass exhibit typical characteristics of lignocellulosic material pyrolysis. The mass loss (10.42 wt.%) till 200 °C is related to evaporation of moisture adsorbed on the sample. The main decomposition of the biomass occurred in the temperature range between 200 and 500 °C. The sharp peak at 283 °C is attributed to hemicellulose and a second sharp peak at 354 °C belongs to the cellulose. A clear DTG peak of lignin is not observed as lignin decomposes between 200 and 500 °C. Lignin decomposition happened throughout the temperature in the range of 200–700 °C. However, the main area of weight loss takes place at higher temperatures.

3.3. Char yields

The effect of pyrolysis temperature and heating rate on the char yield is given in Fig. 2. A rise of pyrolysis temperature and heating rate results in a reduction in the yields of char. The high heating rate is likely to enhance the depolymerization of biomass into primary volatile components which at the end retard the char yield. At the high heating rate, the secondary pyrolysis dominates and the secondary reaction said to the formation of the gaseous component. The effect of heating rate on the char yield is more noticeable and potent at lower temperatures (Ateş et al., 2004; Ayllon et al., 2006).

Fu et al. (2012), Hmid et al. (2014) and Angın (2013) reported a decrease in a biochar yield of rice straw, olive mill waste, sunflower cake respectively on increasing the heating rates and temperatures. At high temperatures, char formed during the primary pyrolysis reaction undergoes the secondary reactions and increases the liquid and gaseous products at the cost of solid char. Low temperature is suitable for high char yield as at high temperature, energy is given to the biomass may exceed the bond cessation energy which supports the release of the volatile components of the biomass. These volatile constituents of biomass come out in the form of gas resulting in less char yield. Fig. 3 shows the yield of char (22–35%) obtained in the pyrolysis of the CP. Similar char yields have been observed before (Demiral and Kul-Çemrek, 2014; Choi et al., 2012). The studied biomass has a high content of lignin and for this reason, the lignin is the main contributor to the formation of char.

3.4. Ultimate analysis

The results of the elemental analysis of chars acquired at different pyrolysis temperatures and heating rates are shown in Table 2. With a raise in the pyrolysis temperature from 400 to 700 °C, the carbon content of the chars increased however, the hydrogen and oxygen content reduced for all heating rates. Loses in H and O content at high pyrolysis temperature are attributed to cleavage and cracking of weak bonds within in biochar structure (Xie et al., 2015). As the temperature rose, H/C and O/C atomic ratios gradually decreased, indicating that the chars became increasingly more aromatic and carbonaceous (Fu et al., 2012). The O/C ratios of the chars were the lowest at 700 °C, while the O/C ratios of chars the highest at 400 °C.

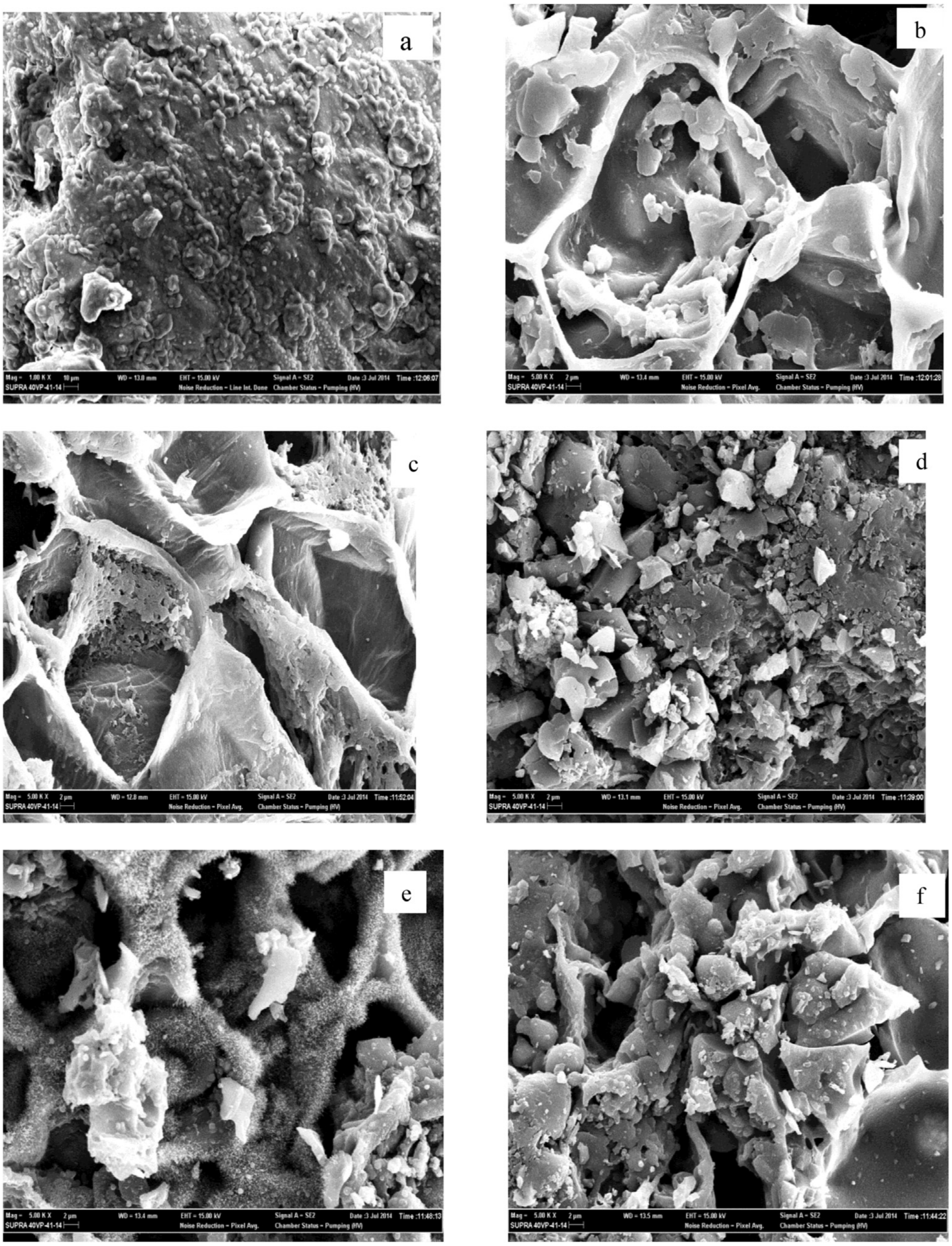

Fig. 4. Scanning electron micrographs of a) raw material and chars produced at b) 400 °C, c) 500 °C, d) 550 °C, e) 600 °C, f) 700 °C.

The thermal value is an important value indicating the energy content of the fuels. The HHVs of the chars are increased by 74% compared to original the raw material The elemental content and HHVs of the CP chars were resembled to those of char produced from other biomass samples (Mullen et al., 2010; Lee et al., 2013; Apaydın-Varol and Pütün, 2012). According to analysis of the standard classification of coals (ASTMD388-1) the HHVs of the chars were comparable with those of solid fuels ranging from lignite to anthracite (Fu et al., 2012). Therefore, the CP chars have potential usage as solid fuels.

Under both heating conditions, the chars became more carbon rich and higher in calorific value as the temperature increased. The chars obtained by fast pyrolysis show a higher amount of oxygen than chars obtained by slow pyrolysis due to the high heating rate and the limited retention time. They can be also burned in a steam boiler with an appropriate emission control alone or mixed with

Table 3
BET analysis of chars.

Surface area	Micropore volume	Total pore volume	Micropore area	Average pore width
95.75 m^2/g	0.034 cm^3/g	0.044 cm^3/g	74.8338 m^2/g	626.62 Å

Table 4
XRF analysis of raw material and ash.

Component	Raw material	Char ash
	Concentration (ppm)	Concentration (ppm)
Mg	0,882	2644
Al	0,108	0062
Si	0,139	0105
P	6147	9833
S	1522	0,425
Cl	0,195	3890
K	27,193	47,592
Ca	22,681	22,106
Fe	0,492	3492
Ni	0,139	0072
Cu	0,152	0898
Zn	0,198	1230

other fuels. Generally, high nitrogen content of char can provide nutrients to soil and enhance crop productivity (Sanna et al., 2011). Nitrogen contents altered in the range of 4.92–5.47%; 4.47–5.77% and 6.53–5.24% for the heating rates of 10, 100, 200 °C/min, respectively, at the various pyrolysis temperatures.

3.5. FT-IR analysis

The FT-IR analyses indicated that the functional groups of chars obtained at different pyrolysis heating rates were quite similar rand that aromatic and aliphatic groups are predominant (Fig. 3). For all materials wide and strong OH stretching bands observed between 3300 and 3400 cm^{-1} are ascribed to the presence of phenols, alcohols and carboxylic acids. Two strong bands observed peaks at 2850–2950 cm^{-1} and ~1470 cm^{-1} shows C-H stretching and deformation vibration from alkanes, respectively. The intensity of these peaks in chars reduced with an increase in the pyrolysis temperature. This can be due to the enhancement of aromatic structure in chars with increasing pyrolysis temperature. Sharma et al. (2014) studied FT-IR characterization of lignin chars obtained at different temperatures and showed that the broad band for the OH in-plane bend decreased with increase in pyrolysis temperature. Stretching absorption band between 1750 and 1600 cm^{-1} is assigned to carbonyl C =O present in carbonyls ketones aldehydes or ester groups and to C =C present in olefinic vibrations in aromatic region. Aromatic structure in the samples is confirmed by very strong absorption bands around 1060 cm^{-1} that shows the presence of lignin.

3.6. SEM and BET analysis

Fig. 4 shows the comparison of SEM images of CP and its chars. Advancement of the char surface morphology with pyrolysis temperature can be seen by investigating the SEM images of the char particles obtained under different temperatures. As exhibited in Fig. 4 recognizable structural distinctions had occurred during the pyrolysis process. A carbonization process which is carried out at high temperatures results in the demolition of raw materials. Pores open when volatile substances run off in the raw material during this process. The raise in pyrolysis temperatures causes the amorphous and heterogeneous structure of CP chars. Chars particles showed several cavities of different sizes and irregular shapes, while the surface of CP was flat with fewer cavities. The vesicles occurred through a melt phase of cellular components. From a phenomenological point of view, a gradual release of different volatile compounds occurs as the temperature raises during devolatilization (Guerrero et al., 2008; Liu et al., 2010). Guerrero et al. (2008) studied the pyrolysis of rice husk and eucalyptus and found that thermal treatment develops porosity in the chars, resulting in micro-macroporous structured particles.

For the characterization of chars one of the important parameters is surface area or surface morphology. The surface area of char is important because it may strongly affect the reactivity and combustion behavior of the char. It is known from previous studies that the pyrolysis of biomass generally develops porosity in the chars, resulting in a micro and macroporous structured particles (Guerrero et al., 2008). BET surface areas of 700 °C pyrolysis and 100 °C/min heating rate chars were calculated and given in Table 3. Keeping in mind that biomass materials have low surface areas between 0.5 and 2 m^2/g after applying thermal treatment resulting product reached larger surface area. This increment in surface areas

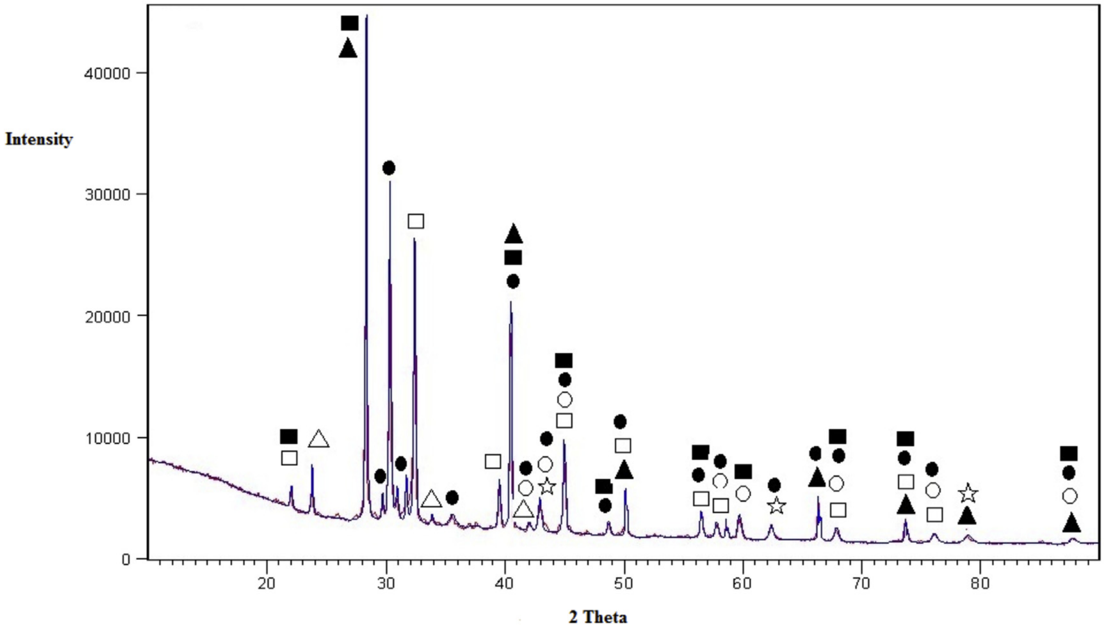

Fig. 5. XRD spectrum of ash produced from char; Δ:K, □: Ca_2SiO_4, ■:SiO_2, ○:$KClO_2$, ●:$CaMgSi_2O_6$.

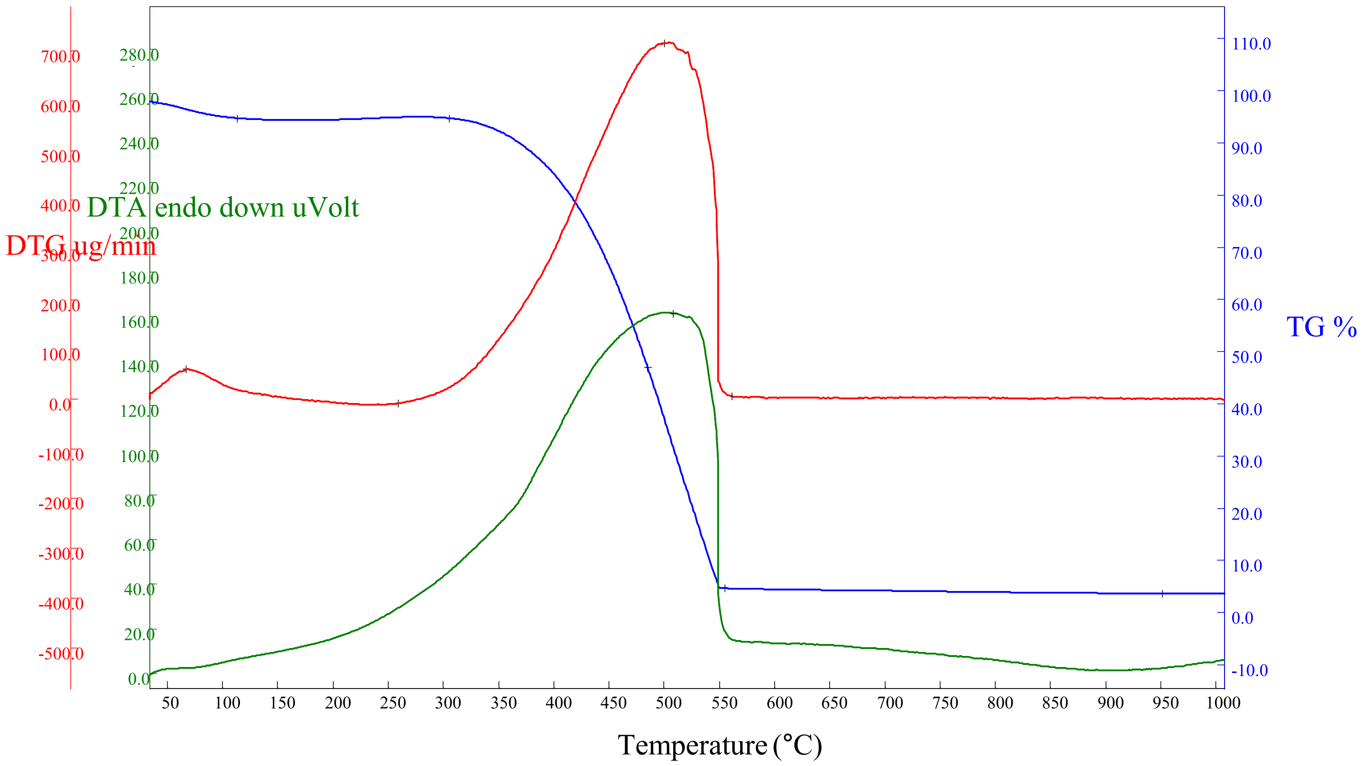

Fig. 6. TGA, DTG and DTA analysis curves of char produced from CP under air atmosphere.

can be attributed to the presence of high amounts of lignin in the biomass sample (Stahl and Henrich, 2009). The surface area (95 m^2/g) with pyrolysis is quite a good result. However, it is not sufficient to be used as active carbon. Favorable conditions which are used for the production of activated carbon as a cheap adsorbent of pollutants with its physical and chemical methods can be determined when the surface area of the solid product is taken into account. Wang et al. (2010) improved properties of prepared biochar via

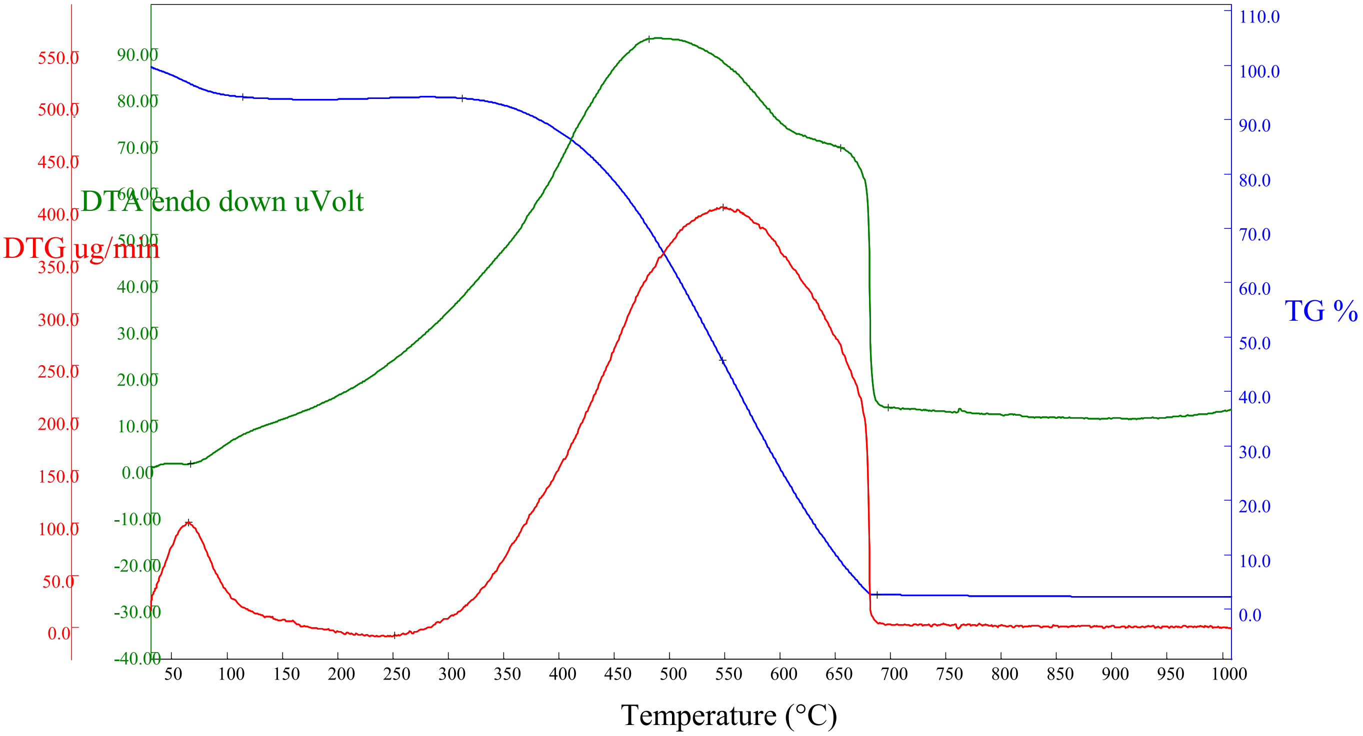

Fig. 7. TGA, DTG and DTA analysis curves of char produced from CP under nitrogen atmosphere.

sulfuric acid hydrolysis of waste rice husks under atmospheric pressure and low temperature. The produced biochar at 95 °C and 6 h had a high surface area of 2700 m^2/g. The large microsurface area constitutes 77% of the total surface area. It can be considered as a superior feature of chars that can be effectively used in many areas.

3.7. XRF and XRD analysis

List of the concentrations of inorganic elements in the chars can be seen in Table 4. K is dominant followed by Ca and P respectively in the char of CP. K, P and Mg content in char are increased compared to biomass. Fahmi et al. (2007) found that the char yield increases as metal content increase; and inorganics, especially K, had a strong catalytic effect during process. Due to the abundance of CP biochars in mineral elements such as phosphorus and potassium, together with carbon and nitrogen, chars might be utilized as soil amendments.

The XRD analysis of biochar ash is given in Fig. 5. According to the analysis, SiO_2, $CaMgSi_2O_6$ and KCl compounds are the most dominant in a wide range of structure of examples. Then K, Ca_2SiO_4, $KClO_2$ and MgO phases are also found. These results are also compatible with XRF.

3.8. Thermal analysis of char

Thermo-gravimetric analysis of char was carried in nitrogen and air atmosphere. TG and DTG curves are shown in Figs. 6 and 7. Char degradation occurred temperatures between 300 and 500 °C and 300 and 700 °C at nitrogen and air atmospheres respectively. The solid residue at the end of the experiment was approximately 4% of the initial char dry weight sample for both atmospheres. This may be attributed to the content of the mineral matter in the chars.

4. Conclusions

Char production from fast and slow pyrolysis of cherry pulp was examined employing a tubular fixed bed reactor for various pyrolysis temperatures and heating rates. Maximum char yield was attained as 31.25% with, pyrolysis temperature of 400 °C, heating rate of 10 °C/min under nitrogen flow rate of 100 cm^3/min and mean particle size of 1.18 mm. When considering the yields and characteristics of the chars, it is apparent that cherry pulp is a reasonable feedstock for char production and can be a promising candidate for the near future biofuel applications. Production of char via pyrolysis is considered to be one of the sustainable solution that may be economically profitable in large scales and minimize environmental concerns especially in terms of waste minimization, carbon sequestration, soil amendment, energy/heat supply value added chemicals, development of rural areas.

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