AGRICULTURAL WASTE TO ENERGY APPROACH IN NORTHERN CYPRUS

Abstract

Agricultural wastes of each country have high potential to contribute energy generation. However, high moisture content and low energy density of these wastes prevents their direct combustion and upgrade to denser energy carriers is required. Costs associated with these upgrading methods are always a barrier in front of efficient utilization and results with natural degradation in open dumping sites or landfills. This study investigated possibility of meeting charcoal demand by using two agricultural wastes; solid olive mill residue (SOMR) and orange peel in Northern Cyprus. Results indicated that these two agricultural wastes have high potential to replace woody charcoal and make Northern Cyprus a self-charcoal sufficient country. The importance of study is showing that if the selection of conversion method is done by considering properties of agricultural wastes, economy and needs of country, they can efficiently contribute energy generation.

Keywords: Agricultural Waste, Carbonization, Charcoal, Orange Peel, Solid Olive Mill Residue.

KUZEY KIBRIS'TA TARIMSAL ATIKTAN ENERJİYE YAKLAŞIMI

Özet

Tüm ülkeler için tarımsal atıklar enerji üretimine koyabilecekleri potansiyel katkı dolayısı ile önem taşımaktadır. Bununla birlikte bu atıkların yüksek nem içerikleri ve düşük enerji yoğunlukları, uygun yöntemlerle enerji yoğunluğu daha yüksek yakıtlara dönüştürülmelerini gerektirir. Bu dönüştürme yöntemlerinin pahalılığı, tarımsal atıkların verimli bir şekilde kullanılmasını engellemekte ve bu atıkların açık alanlarda çürümeye bırakılması ile sonuçlanmaktadır. Bu çalışmada Kuzey Kıbrıs'ta bulunan tarımsal atıklar; pirina ve portakal kabuğundan bio-kömür üretilmiş ve bu atıkların Kuzey Kıbrıs'ın bio-kömür ihtiyacına koyabileceği katkı araştırılmıştır. Sonuçlar Kuzey Kıbrıs'ın pirina ve portakal kabuğu kullanarak, kendi bio-kömür ihtiyacını karşılayan bir ülke olabileceğini göstermiştir. Bu çalışma, eldeki tarımsal atıkların özelliği, ülke ekonomisi ve ihtiyaçları gözönünde bulundurularak seçilen bir dönüştürme yöntemi ile tarımsal atıkların etkin şekilde enerji üretimine katkı koyabileceğini göstermesi açısından önemlidir.

Anahtar Kelimeler : Bio-Kömür, Karbonizasyon, Pirina, Portakal Kabuğu, Tarımsal Atık.

Introduction

It is estimated that 19% of global final energy consumption in 2012 was provided by renewable energy resources, where 9% of total was coming from traditional biomass (Renewables 2014 Global Status Report 2014). Charcoal is a solid fuel obtained from

carbonization of biomass, mainly from wood, and used for outdoor cooking. According to statistics of Food and Agriculture Organization (FAO), 51 million tonnes of wood charcoal was produced in 2012, with an increase of 5% over the period of 2008-2012 (Food and Agriculture Organization 2012). Many countries such as Germany, China, Japan, Malaysia and Republic of Korea do not have enough wood sources to meet own charcoal demand and high costs are paid for importing charcoal (Steierer 2011). As a part of Mediterranean island, Northern Cyprus is also a charcoal importing country and 250,000 $ has been paid for importing 529 tonnes of charcoal in 2010 (Ministry of Economy and Energy 2010). Local agricultural wastes are good candidates for charcoal production and replacing imported woody charcoal. Northern Cyprus has typical Mediterranean climate where main agricultural products are orange and olive. Ministry of Food, Agriculture and Energy of Northern Cyprus announced that 92,000.00 tonnes of orange (Valencia, Washington and Shiamouti) harvested in 2012 and around 37,797.00 tonnes of harvested orange was used for concentrated orange juice production (Ministry of Food, Agriculture and Energy: 2012). Orange peel is one of fundamental agricultural wastes produced from orange juice production. Also, Ministry of Food, Agriculture and Energy of Northern Cyprus has been announced that 7,752.00 tonnes of olive was harvested in 2012 (Ministry of Food, Agriculture and Energy: 2012) and 80% of harvested olive was used for olive oil production in three phase olive mills.

Solid olive mill residue (SOMR) is an agricultural waste produced from olive oil extraction. This study investigated the possibility of being self-charcoal sufficient country for Northern Cyprus by using two agricultural wastes Solid Olive Mill Residue (SOMR) and orange peel. These agricultural wastes were carbonized for charcoal production. Ultimate analysis and proximate analysis of produced charcoals were conducted for characterization of products. Ultimate and proximate analysis of imported commercial hardwood charcoal (CHC) is conducted as well for investigating possibility of replacing CHC with charcoal produced from solid olive mill residue and orange peel.

Materials and Methods

Solid olive mill residue (SOMR) and orange peel were supplied from local Aydın Olive Mill and Meysan Citrus Concentrated Juice Company respectively. Orange peel and SOMR are dried at 105 °C until their mass reach to a stable point before carbonization. Measured moisture content of raw SOMR and raw orange peel were 40% and 20% respectively. Carbonization process was carried out at 397°C with heating rate of less than 15 ^{O}C min^{-1} under the flow of nitrogen gas for 30 minutes. The schematic representation of used carbonization equipment is given in Fig. 1. The carbonization equipment consists of an electric heater and a glass tube. The glass tube has height of 0.29 m and radius of 0.02 m. Each carbonization process was conducted with 5 g of raw SOMR or orange peel under the flow of 0.2 Lmin^{-1}. In order to deplete the glass tube of any oxygen before starting the process, 50 mL/min of nitrogen was passed through for 10 minutes. Each carbonization experiment was repeated twice, and results are given as the average of the two experiments.

Ultimate and proximate analyses were conducted for characterization of the produce charcoals. Thermo Finnegan Flash EA 1112 Series Element Analyzer is used for ultimate analysis. Atomic ratios; H/C and O/C of produced charcoals were also calculated and compared with H/C and O/C ratio of CHC. Charcoal samples were dried at 105 °C until their mass reach to a stable point before proximate analysis. Volatile matter, ash and fixed carbon content of produced charcoals and commercial hardwood charcoal were determined by proximate analysis. Volatile matter content of moisture free charcoal samples was measured by heating in a moisture free covered crucible up to 950 °C and keeping at that temperature for 6 minutes.

Volatile matter (VM) content of samples was determined according to equation (1);

$$VM = 100 \times \frac{M_{charcoal} - M_{vm}}{M_{charcoal}} \quad (1)$$

Where, $m_{charcoal}$ is the mass of moisture free charcoal before heating up to 950 °C and m_{vm} is the mass of remaining charcoal after heating up to 950 °C and keeping at that temperature for 6 minutes. Ash content was measured after determination of volatile matter content. Volatile and moisture free charcoal samples were heated up to 750 °C and held at that temperature for 6 hours in an open crucible. Ash content was calculated according to equation (2);

$$Ash = 100 \times \frac{M_{ash}}{M_{charcoal}} \quad (2)$$

Where, mash is the remained mass after heating up to 950 °C and keeping at that temperature for 6 hours. Fixed carbon (FC) content of produced charcoals was determined according to equation (3);

$$FC\% = 100 - VM\% - Ash\,\% \quad (3)$$

Higher Heating Value (HHV) is also an important parameter for charcoal characterization. In this study ultimate analysis results were used for determination of HHV of produced charcoals. HHV of produced charcoals were calculated according to equation derived by Demirbaş et al. (Demirbaş et al. 1997), given as:

$$HHV = \left(33.5\,C(wt\%) + 142.8\,H\,(wt\%) - 15.40\,O\,(wt\%) - 14.5\,N(wt\%)\right) \times 10^{-2}\,\left(\frac{MJ}{kg}\right) \quad (4)$$

Results

Ultimate analysis results and charcoal yields of produced charcoals are given in Table 1. According to results, SOMR has higher charcoal yield of 37.15% compared charcoal yield of orange peel which is 33.98%. Ultimate analysis results showed that both charcoal samples have higher carbon contents compared to commercial hardwood charcoal (CHC). SOMR charcoal has 3.82% and orange peel charcoal has 7.32% more carbon compared to CHC. Oxygen content of both produced charcoals is less than oxygen content of CHC. Oxygen content of SOMR charcoal is 8.36% less where the oxygen content of orange peel charcoal is 3.8% less than CHC. Oxygen and carbon content are two important parameters for characterization of produced charcoals since both have high contribution on HHV as given in equation (4). Hydrogen content of all, SOMR, orange peel and CHC is almost same and the differences do not exceed 0.4%.

TABLE 1

Proximate analysis results of produced charcoals are given in Table 2. Ash content of SOMR charcoal is 3.76% higher than the ash content of CHC where ash content of orange peel charcoal shows contrary result. CHC has 5.03% more ash compared to orange peel charcoal. Volatile matter content measurements of produced charcoals showed that both SOMR charcoal and orange peel charcoal have higher volatile matter content compared to CHC. Orange peel charcoal contains 43.21% and SOMR charcoal have only 8.27% more volatile matter compared to CHC.

TABLE 2

It is also detected that CHC has highest fixed carbon content. Higher volatile matter content of produced SOMR and orange peel charcoals results with less fixed carbon content compared to CHC. SOMR charcoal contains 12.03% less fixed carbon compared to CHC and the difference reach to 38.54% for orange peel charcoal. Fig. 2 and Fig. 3 shows the H/C and O/C ratios of produced charcoals and CHC respectively. Results showed that, CHC have highest H/C and O/C ratio where SOMR charcoal has lowest H/C and O/C ratio. Higher Heating Value (HHV) is another important measurement for comparing the energy content of produced charcoals. Fig. 4 shows HHV values of SOMR charcoal, Orange Peel charcoal and CHC. Results showed that orange peel charcoal has 13.6% higher HHV compared to CHC where SOMR charcoal has 7.5% higher HHV.

According to statistics of Ministry of Food, Agriculture and Energy approximately 6,201.00 tonnes of olive is milled for olive oil production in year 2012 (Ministry of Food, Agriculture and Energy; 2012) . It is well known that olive oil production by the three-phase system produces 20% oil, 50% olive mill wastewaters and 30% three-phase olive mill solid wastes (Rincón et al.; 2012). Statistics show that Northern Cyprus has approximately 1860.00 tonnes of SOMR with 40% moisture content. Charcoal yield results indicate that, Northern Cyprus can produce approximately 414.00 tonnes of SOMR charcoal annually. Statistics of Ministry of Food, Agriculture and Energy, also indicates that approximately 18,898.00 tonnes of orange peel is generated annually with 20% moisture content. It is known that, during orange juice production, only around the half of the fresh orange weight is transformed into juice (Braddock, 1995;, Rezzadori et al., 2010), generating great amounts of waste (mainly orange peel). Charcoal yield calculations indicated that, Northern Cyprus can produce 5,137.00 tonnes of orange peel charcoal annually.

Discussion

Solid Olive Mill Residue and orange peel are two important agricultural wastes in Northern Cyprus. In this work carbonization of these wastes for charcoal production has been investigated. Elemental composition, volatile matter content, ash content, fixed carbon content and HHV of produced charcoals were compared with commercial hard wood charcoal. Ultimate analysis results showed that elemental composition of SOMR charcoal is much more similar to elemental composition of CHC compared to orange peel charcoal. Besides elemental composition H/C and O/C ratios are important parameters for measuring process efficiency and produced fuel quality. Reduced H/C ratio is a measure of carbonization efficiency (Nguyen et al., 2004), where reduced O/C ratio reflects the degree of sample oxidation (Ascough et al., 2010). Also, reduced O/C ratio is a potential indicator of both hydrophobicity and polarity, where decrease in polar surface groups results with reduction of fuel affinity with water molecules (Manyà, 2012). It can evidently be seen that both SOMR and orange peel are carbonized more efficiently and more hydrophobic charcoal is obtained from these wastes compared to CHC. Hydrophobicity of a solid fuel is important for its stability. More hydrophobic fuel can be stored for longer periods without degradation. Proximate analysis results indicated that ash content of SOMR charcoal is more than CHC. High ash content inhibits the combustion of charcoal because oxygen may not penetrate through the ash easily for burning (Syamsiro et al., 2012). It is also detected that volatile matter content of charcoal produced from orange peel is more than double of volatile matter content of CHC. Complete combustion of volatile matter leads to dark smoke, heat loss and pollution hazard (Patel and Gami, 2012). However, high HHV of SOMR and orange peel charcoal showed that both wastes are attractive sources for charcoal production. Blending two charcoals will be a good option to prevent combustion problems due to higher ash content of SOMR charcoal and higher volatile matter content of orange peel. Beside contribution to energy generation, utilization of these agricultural wastes is also important by means of solid waste management in Northern Cyprus. Currently a small fraction of SOMR is combusted in brick factories and small amount of orange peel is used for animal feeding. Considerable amounts of these agricultural wastes are left for natural degradation in open landfills. Solid Olive Mill Residue mainly consists of water, seed and pulp and is a potentially harmful by-product for the environment, because of the phytotoxic and antimicrobial properties, low pH, relatively high salinity and organic load, and the phenolic and lipid constituents (Gómez-Muñoz et al., 2012). Also, natural degradation of orange peel in open landfills results with leakage of yellow water which have high pollution potential because of its organic content and its leakage to soil must be prevented (Tavares et al. .,1998). The costs associated with solid waste disposal on islands are especially challenging with the limitations of scale, labor costs, increasing energy costs as well as the repair and maintenance of machinery (Sullivan and Smith, 2014). Energy generation from agricultural wastes is an attractive option especially small island like Cyprus. However, high moisture content and low energy density of these wastes prevents their efficient combustion.

Agricultural wastes must be converted to more energy denser energy carriers with a suitable upgrading method. There are exists several upgrading methods for raw agricultural wastes like pyrolysis, gasification, aerobic or anaerobic digestion. Each method has its own advantages and converts raw agricultural waste to solid, liquid or gas energy carriers. The upgrading method must be selected by considering the properties of raw agricultural wastes, their collection/transportation eases, economy and needs of country. Northern Cyprus produces charcoal from wood but cannot meet demand. For such country, carbonization of agricultural wastes will not require additional investment costs for a carbonization system. It is also well known that collection and transportation of agricultural wastes results with additional costs to utilization solid wastes (Apaydın, 2005). Another advantage of using SOMR and orange peel for charcoal production is their low transportation/collection costs. Both wastes are produced in bulk in relevant mills and factory. If it is also considered that; Northern Cyprus do not have long transportation infrastructure, transportation of these wastes will not be a big concern. Statistics used in this work belongs on in 2012. However, the average of three years (2010, 2011, and 2012) production rates does not deviate more than 10 % for SOMR and 14% for orange peel (Ministry of Food Agriculture and Energy, 2012).This study revealed that Northern Cyprus can be a self-charcoal-sufficient country by using agricultural wastes SOMR and orange peel. Also, this study is important because it shows that if suitable upgrading method is used, agricultural wastes can efficiently contribute to energy generation even for countries with low economies like Northern Cyprus.

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Table Titles

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Fig. 1. Schematic representation of carbonization system.

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Table1. Ultimate analysis results of SOMR charcoal, orange peels charcoal and commercial hardwood charcoal.

Charcoal	Charcoal Yield	C(wt %)	H(wt %)	N(wt%)	O[a] (wt%)
SOMR	37.15	66.10	4.25	1.22	18.61
Orange Peel	33.98	69.60	4.90	1.3	23.17
CHC	-	62.28	4.69	-	26.97

(a: dry basis)

Table 2. Proximate analysis results of olive mill residue, orange peel and hardwood charcoals.

Charcoal	Ash (wt %)	Fixed Carbon (wt %)	Volatile Matter (wt %)
SOMR	9.82	42.66	47.52
Orange Peel	1.03	16.51	82.46
CHC	6.06	54.69	39.25