BIO-ENERGY POTENTIAL FROM LEMON ORCHARDS

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Abstract
Biomass has increasing popularity day by day as the fossil fuel sources consumed away in the world. Biomass can be both plant based and animal based residues. The potential of plant based biomass resources is huge but, most of these sources are idle. Not used for any purposes unfortunately. Pruning residues from fruit orchards are a good solution to compensate this energy source. Lemon is a popular fruit especially in the Mediterranean region of Turkey. Thus, is a good source for biomass. In this study, the pruning residues of lemon trees were converted into solid bio-fuel in the form of pellets. Thermal properties such as; gross calorific value, ash content and flue gas emissions of the produced pellets were analyzed. Also, some physical mechanical properties were determined. Bulk and pellet particle densities were 521.33 and 1236.70kg.m^{-3}, respectively. Firmness of the pellets was 2951 N and mechanical durability (MD) was 88.57%. Results showed us that the pruning residues of lemon orchards could be a good solution to be utilized as solid bio-fuel both in terms of physical-mechanical and thermal properties.

Key words: *biomass; energy; lemon; pellet; pruning.*

INTRODUCTION

As we are living in an energy age and any sources of energy are vital in today's world. The main source of energy comes from fossil fuels but they are subject to disappear in the coming years. People are in seek of alternative energy sources to survive. Biomass can be a good solution for that since it's plant and animal based residues. There is a huge residue potential in the world due to agricultural production. Unfortunately, most of these potential is not used for any purposes and they are just left on the fields or on the gardens for natural decomposition or just burned randomly near the garden. That is the case for lemon punning residues, as well (Fig.1.).

Fig. 1 Random burning of lemon pruning residues

Shaping the grinded material under pressure to smaller sizes (approx. 30 mm) is called pelleting *(Öztürk, 2012)*. Pellets can be produced from sawdust, wood chips, tree barks, agricultural products, straw, hazelnut shell, almond shell, walnut shell and even from waste papers. The density of material is increased and the transportation and storing costs are decreased by pelleting process. Moreover, homogeneity is provided in size and shape which make them more suitable for automatic feeding systems and effective usage of material is provided *(Werther et al., 2000; Mani et al., 2003; Holm et al., 2006; Nilsson et al., 2011; Theerarattananoon et al., 2011; Celma et al., 2012)*. Pelleted biomass is low and uniform in moisture content. It can be handled and stored cheaply and safely using well developed handling systems for grains *(Fasina & Sokhansanj, 1996)*. Turkey is an important producer of lemon in her region. Also, she is an important producer of fresh fruit and vegetable with about 51 million tons of production. Turkey's citrus production reached approximately 4.29 million tons in the last decade, with an increase of 44% *(TUIK, 2018)*. Lemon supply and consumption in Turkey is presented in Tab. 1 *(MFAA, 2018)*.

Tab. 1 Lemon supply and consumption in Turkey (1000 tons)

Season	2013/14	2014/15	2015/16	2016/17
Production	726	725	751	851
Import	2	2	3	4
Total supply	728	727	754	855
Export	404	449	394	493
Consumption	324	278	359	362

Lemon orchards need maintaining and care in order to keep and enhance the yield. The most common procedure for this is pruning, of course. The crown of the tree is pruned periodically to strengthen the tree and to boost the productivity. Hence, a big amount of pruning residue is produced in those particular periods and this wood based biomass is not used for any purposes. The aim of this study is to utilize lemon orchard pruning residues as solid biofuel in the form of pellets. Some physical-mechanical and thermal properties of produced fuel pellets such as; gross calorific value, ash content and flue gas emission values were analyzed.

MATERIALS AND METHODS

This study is carried out in labs and workshop of Agricultural Machines and Technologies Engineering Department of Samsun Ondokuz Mayıs University in Turkey. Pruning residues of lemon tree were provided from lemon orchards in Mediterranean Region of Turkey (Fig. 2). Up to date European standards (*EN 14961-2 & EN ISO 17225-6*) were taken as a reference for this research.

Fig. 2 Pre-fragmentation of lemon branches

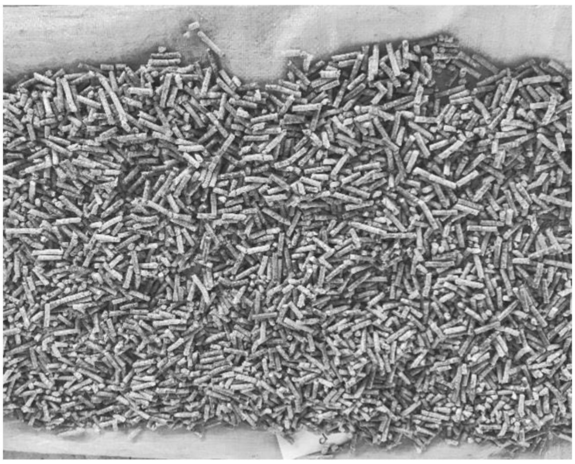

Fig. 3 Pellets from lemon pruning residues

The pre-chopped material was sun-dried under normal conditions until their moisture content was reduced to M10 (8-10 %). Then the dried material was ground in a 3-kW electric hammer mill consisting of 8 hammers rotating at a speed of 2,850 rpm. Once particles of the required sizes PS: 4 mm was obtained, moisture contents were re-measured, and the particles were pelleted using a pelleting machine (Fig. 3).

Lower heating value of pellets were determined by a calorimeter according to the instructions given in standard (*EN 14918*, 2009). Before testing, the pellets were disintegrated in a shredder and kept at 105 ºC for 24 hours to remove the moisture. Samples dried at a weight of 0.5-1 g were burned in oxygen atmosphere in a calorimeter bomb under standard conditions and the calorific value was automatically determined in $cal.g^{-1}$ according to the increase in the temperature of the water in the calorimeter chamber and the average actual heat capacity of the system. Then the values are converted into $MJ.kg^{-1}$ as specified in standard (*EN 14961-2, 2010*). The ash contents of the pellets were determined using an ash furnace according to standard (*EN 14775, 2009*) and the flue gas emissions like O_2(%), CO(ppm), CO_2(%), NO(ppm), NO_x(ppm) were measured and recorded with a gas analyzer.

RESULTS AND DISCUSSION

Ash content of the pellets made from lemon pruning agricultural residue was found as 5.20%, which is in line with the reference value (A10≤10%) given in standard (*EN ISO 17225-6, 2015*). Heating value of pellets was found as 18.60 $MJ.kg^{-1}$. That is also compatible with the value (Q14.5≥14.5 $MJ.kg^{-1}$) indicated in the above mentioned standard. The results showed us that the heating value of pellets produced from lemon tree pruning residues are higher than the wood (17.57 $MJ.kg^{-1}$). That is a promising result indeed. Especially, when the huge idle potential is concerned. The flue gases of the pellets are presented in Tab.2., below.

Tab. 2 Flue gas emissions of pellets

Water content after burning (%)	NOx (ppm)	CO_2 (%)	O_2 (%)	CO (ppm)	NO (ppm)
8.23	85.66	4.16	16.73	566.67	81.33

All the measured emission values were in the limits given in Regulations for Air Pollution Control (*IKHKKY, 2014*). Ash content was higher than the ash content of pellets produced from hazelnut husks (7.19%) (*Gürdil et al., 2016*). That can be due to content of material since the pruning residues of lemon trees are woody based elements so their ash contents could be higher than a plant based material. But on the other hand, CO and NO concentrations were lower than plant based materials (*Gürdil et al., 2016*). CO_2 emission was higher in fuel pellets produced from lemon pruning residues. But, this is an expected resulted because the higher CO_2 emissions the better burning of material. Physical mechanical properties of pellets are in Tab. 3.

Tab. 3 Some physical mechanical properties of pellets

Bulk density ($kg.m^{-3}$)	Particle density ($kg.m^{-3}$)	MD (%)	Firmness (N)
512.33	1236.70	88.57	2951

As compared to the results of previous researches bulk and particle densities were slightly lower than that of pellets from plant based residues. But, firmness of pellets was higher than them. As a conclusion the pellets produced from lemon orchard pruning residues was found to be very suitable in order to be used as bio-pellets.

CONCLUSIONS

Utilization of idle lemon orchard residues as source of solid biofuel in the form of pellets were investigated in this study. The pellets were produced with 4mm PS and M10 moisture content. Thermal properties of fuel pellets such as; lower heating value, ash content and flue gas emissions were determined. All the tests were done according to the latest EU standards. The results showed that the fuel pellets have very good thermal properties as a fuel. Besides, as from the environmental point of view flue gas emissions were within the defined limits. We believe in that further studies of this kind will help agricultural engineers, scientific researches, farmers and even the policy makers to think more globally and wisely for the future and will definitely have a positive contribution to sustainable development in the world.

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