Briquetting of greenhouse pepper crop residues

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Abstract: Greenhouse cultivation is widespread in Turkey, and tomato, pepper and eggplant among the vegetables are grown densely in greenhouses. Every year, huge amounts of crop residue are produced from these greenhouses, and the vast majority of these residues are dumped in landfills and out of the greenhouses without evaluating in any way. These crop residues are organic matters and can be evaluated as a biomass energy source. In this study, dried ground greenhouse pepper crop residues were briquetted in the hydraulic press with maximum capacity of 210 MPa and a punch-conical die set, and physical properties of briquettes regarding briquette quality were determined. The briquetting experiments were conducted at 7.06 % moisture content (w.b.), 0.732 mm geometric mean diameter of ground pepper crop samples using three pressure levels of 115, 150 and 185 MPa. The briquettes were kept in a room at 20℃ temperature and 50% relative humidity for 7 days to ensure their stabilization. The density, shatter index, tumbler index, water resistance and equivalent humidity content (humidity resistance) of briquettes were then determined. Briquettes were produced with an average diameter of 61.6 mm during the briquetting process. The result of physical tests showed that the produced briquettes were extremely high quality. The maximum density, shatter and tumbler resistance were 1075 kg/m^3, 98.21% and 90.83% at compression pressure of 185 MPa, respectively. Additionally, while the effect of ambient humidity on all briquettes was very limited, they were completely disintegrated when dunked in container filled water for very short time lower than 30 seconds.

Keywords: Greenhouse pepper crop residue, briquette, briquette physical properties, Turkey

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1 Introduction

Energy consumption in Turkey has been increasing rapidly due to increasing population and its being a developing country. While Turkey's energy production was 34 MTEP in 2012, primary energy supply reached 121 MTEP in the same year and the share of production's compensating primary energy supply became 28% at the end of 2012 (ETKB, 2013). The use of clean, domestic and renewable energy sources is very important for Turkey, due to the fact that Turkey's fossil energy sources are limited. Additionally, Turkey's geographical location and large production areas provide advantages in terms of the use of the renewable energy sources. Although Turkey has a big potential for renewable energy sources, the share of these sources in the general energy production is quite low. Among the renewable energy sources, the most important source for Turkey as in the developed and developing countries is biomass and its share was 10% in total energy production in 2012.

Turkey is one of the most important greenhouse centers in the world. Total greenhouse area in Turkey is 30312 ha of which 8293 ha are under glass and 22019 hectares are under plastic (TUIK, 2012). Tomato, pepper and eggplant are grown widely in greenhouses in Turkey. The annual amount of biomass residues produced from tomato, pepper and eggplant crops in the greenhouses is approximately 1690 thousand tons in wet basis (205 thousand tons of pepper crop residue) and 253 thousand tons in dry basis (35 thousand tons of pepper crop residue) (Bilgin et al., 2012). Although huge amounts of crop residues are produced every year from these greenhouses in Turkey, they are either burnt or

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dumped out of the greenhouses or mixed into greenhouse soil after grinding. However, as greenhouse crop residues are materials having low density and high moisture content, the fact that they are burned directly to get energy is not quite effective and it leads to problems in storing and transporting (Figure 1).

Figure 1 A view of pollution caused by disposal and burning of greenhouse crop residues

Therefore, one of the effectively ways to use these wastes is to briquette them. So, a cheap, qualified, eco-friendly and renewable energy source can be obtained and costs of storing and transporting are drastically reduced and combustion characteristics are improved. The residues with briquetting will be recovered into economy and partially reduced dependence on energy imports of Turkey. The briquettes will be used in greenhouse heating, household heating-cooking and co-firing with coal in the centrals of heat and power generation or the thermal power plant.

Nowadays, screw, piston and hydraulic type press technologies are used for briquetting of biomass (Grover and Mishra, 1996). In the studies related to briquetting of biomass, various agricultural and other biomass wastes were used and the results of these studies were given, but no enough study was carried out related to greenhouse crop residues.

Tea waste (Demirbaş, 1999), wood processing residues (sawdust, mulches and chips) (Li and Liu 2000), blend lignite with woody wastes (Beker, 2000), rapeseed cake (Karaosmanoğlu, 2000), olive refuse and paper mill waste (Yaman et al., 2000), palm fiber and shell (Husain et al., 2002), partially pyrolyzed esparto (Debdoubi et al., 2005), different greenhouse plant remains (Callejón-Ferre and López-Martínez, 2009), straw, reed and hemp stalks (Kaķīs et al., 2011), cotton stalk (Akman and Bilgin, 2012), and paper and cardboard waste (Gado et al., 2014) were briquetted in hydraulic press under different briquetting pressures. They explained that the mechanical properties of briquettes improved with an increase in briquetting pressures and the researchers indicated that the produced briquettes could be used as biofuel.

In this study, briquetting of dried and ground biomass residues produced from pepper crops, quite fibrous structure, in greenhouses for utilization as a solid fuel in a hydraulic type press machine at three different pressures were aimed. Physical properties of briquettes such as density, tumbler resistance, shatter resistance, water resistance and equivalent humidity content (humidity resistance) were also measured to determine briquette quality.

2 Materials and methods

2.1 Materials

The experiments were conducted at Akdeniz University, Faculty of Agriculture, Department of Agricultural Machinery.

In this study, dried ground pepper crop residues having fibrous structure produced from greenhouses at the end of harvest were used and no binder material was added during briquetting process. The properties of the material used in experiments are given in Table 1.

Table 1 Properties of ground pepper crop used in the experiment

Material	Moisture content (%)		Geometric mean diameter (mm)		Density (kg/m^3)	Ash content (%)	HHV (MJ/kg dry weight)	
Pepper Crop	7.06		0.732		239	15.83	16.13	
	Sieve analysis and size distribution of material							
	0-0.125 mm	0.125-0.30 mm	0.30-0.425 mm	0.425-0.85 mm	0.85-1.18 mm	1.18-1.70 mm	1.70-2.0 mm	>2.0 mm
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
	3.29	12.09	7.45	24.23	18.16	11.42	6.98	16.38

The maximum compaction pressure of 210 MPa (maximum compaction force of 600 kN) automatic hydraulic press and a punch-die set were used for the briquetting of ground pepper crop residues. The compaction pressure of the hydraulic press can be set in the range from 0 to 210 MPa. The die having a conical form, has inlet diameter of 62 mm and outlet diameter of 60 mm and a height of 200 mm. The punch is a cylindrical form and its diameter and height are 59.5 and 172 mm, respectively (Figure 2).

Figure 2 Hydraulic press and a punch-die set

For the determination of tumbler resistance of briquettes, a tumbling test device which was made according to ASAE S269.4 (2000) standards was used. Its electric motor power and rotation speed were 0.75 kW and 40 r/min, respectively. The outside dimensions of tumbler of briquettes which were put were 300 × 300 × 430 mm and mesh size of hardware covering applied taut to the outside of the frame was 12 mm (Figure 3).

Figure 3 Tumbling test device

2.2 Methods

Firstly, pepper crop residues were collected from greenhouses having 80% moisture content (w.b.), which were shredded into pieces of 1-3 cm long with branches shredding machines driven from PTO of a tractor, then, shredded materials were dried naturally up to 7%-10% moisture content under the sun during a week. Finally, dried materials were ground in a hammer mill with screen opening size of 5 mm and electric motor power of 7.5 kW to mill them in suitable sizes for briquetting process. For each experiment, about 150 g of the pepper crop samples (7.06% (w.b.) of moisture content) were filled fully into the die and briquetted at room temperature without using a binding material in a hydraulic press for duration of 60 s under pressures of 115, 150 and 185 MPa (Figure 4). All briquettes were kept under ambient conditions having 20℃ temperature and 50% relative humidity for 7 days to ensure their stabilization before testing. The briquettes were prepared for each experiment set and the arithmetic mean of the measurements was calculated. While determining shatter and tumbler resistance, pieces broken during the tests were screened with a 20 mm sieve and the pieces retained on the sieve were not considered as lost (CRA, 1987).

Figure 4 Samples of briquette obtained at 185 MPa

Since the briquettes have a cylindrical form, the density is calculated as the ratio of the mass to the sample volume. Thus, briquette density was determined using the method of stereometric which are based on the measurement of the dimensions (e.g. diameter, height). Three briquette samples were used in this method. The briquette mass was measured with a digital balance accurate to 0.001 g, and the diameter and height of briquettes were determined by a digital caliper gauge (precision 0.1 mm).

The tumbler resistance of the briquettes was determined according to ASAE Standard S269.4 (2000). In this test, the samples of five briquettes were weighed, and they were put into the tester. Later, the briquettes were tumbled at 40 r/min for 3 min. At the end of rotating operation, briquettes were removed from the tester and weighed again. Tumbler resistance related to weight loss occurring during the test was calculated as a percentage.

Lindley and Vossoughi (1989) measured the shatter resistance as the percentage loss of weight from shattering. In the shatter resistance test, individual the briquettes were dropped 10 times from a height of 1 m onto a concrete floor. Each briquette was weighed before and after the test. Depending on weight loss occurred during the dropping test, shatter resistance was calculated as a percentage.

The water resistance is traditionally tested in immersions tests. Lindley and Vossoughi (1989) measured the water resistance as the percentage of water absorbed by a briquette when immersed in water. Each briquette was dunked in water at 27 ℃ for 30 s and the water resistance of briquettes was calculated as a percentage depending on weight increase of briquettes. Also, the elongation, swelling and the time elapsed for completely disintegration of each briquette were recorded.

In the equivalent humidity content (humidity resistance) test, briquettes were kept in a room of 20 ℃ temperature and 50% humidity for 21 days. Each briquette was weighed before and after the test. Depending on weight increase occurred during the storage, humidity resistance was calculated as a percentage.

3 Results and discussion

The results of physical test related to the quality of pepper crop briquettes obtained through different compaction pressures by hydraulic press machine are given in Table 2.

Table 2 Physical properties of pepper crop briquettes regarding briquette quality

Compaction pressure, MPa	Moisture content, %	Density, kg/m^3	Tumbler resistance, %	Shatter resistance, %	Water resistance, %	Humidity resistance, %
115	7.37	942	70.55	96.84	-	99.02
150	7.34	1005	85.45	97.80	-	99.17
185	7.23	1075	90.83	98.21	-	99.29

Moisture content of biomass fuels is highly significant in terms of combustion. As seen in Table 2, while moisture content of pepper crop before briquetting was 7.06%, it was increased very slightly at the end of 7 days. This increase was decreased by the increase in compaction pressure and the lowest moisture content of briquette was 7.23% at 185 MPa. For all the compaction pressure, briquettes were not much affected by the ambient humidity.

Density is one of the important indicators of the quality of briquette. Briquette density is extremely significant in terms of not only reducing the cost of storage and transportation, but also improving the combustion characteristics. Because the storage, handling and transportation of low density materials are very difficult and costly. In addition, when burned, it has a low thermal efficiency and causes more pollution. Although the density of raw material was low and no binder was used in briquetting process, briquette densities for all compaction pressures were found in rather high values. Briquette density increased with the increase of briquetting pressure, and the highest briquette density was found to be 1075 kg/m^3 at 185 MPa. Pepper crop was compacted to a density greater about of 4.5 times at 185 MPa. The results of briquette density were similar to which obtained by Karaosmanoğlu (2000), Li and Liu (2000), El Saeidy (2004), Wilaipon (2009), Yumak et al. (2010), Gado et al. (2014).

Briquettes were quite strong according to the results of tumbler resistance in Table 2, and it increased with the increase of briquetting pressure and reached a maximum of 90.83% at 185 MPa. After the tumbler testing, the views of the briquettes obtained at the different compaction pressures are shown in Figure 5.

As seen in Figure 5, at the end of tumbler testing, there was no breaking in the briquettes obtained at different compaction pressure, but the losses occurred as a result of crumbled parts from the top corners of all briquettes. The losses decreased with increasing compaction pressure, and all briquettes were all a part at the end of test. This result showed that the briquetting process was very successful.

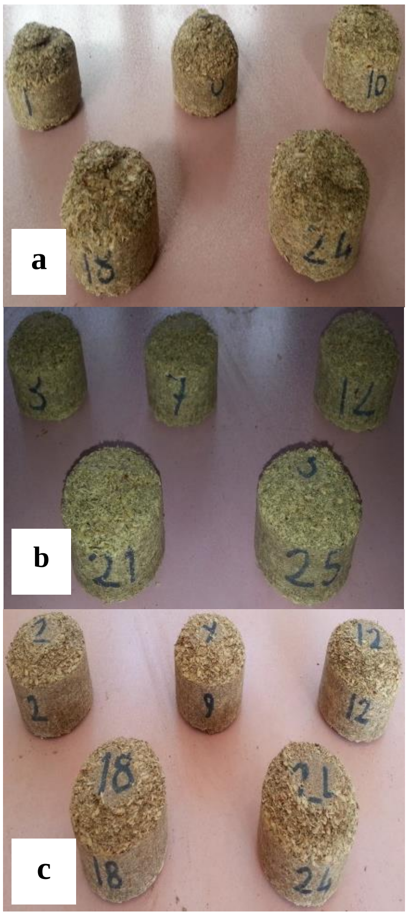

Figure 5 Views after tumbler testing briquettes produced at 115 MPa (a), 150 MPa (b) and 185 MPa (c) compaction pressure

The shatter resistance of the briquettes for all compaction pressures was found close to each other, and extremely high. The results of shatter resistance tests as in tumbler resistance showed that the all briquettes have strong structure. Shatter resistance of briquettes slightly increased with increase of briquetting pressure, and as in tumbler resistance, the highest value of shatter resistance was obtained in the briquettes produced at a compaction pressure of 185 MPa. The views of the briquettes for different pressures after shatter testing are given in Figure 6.

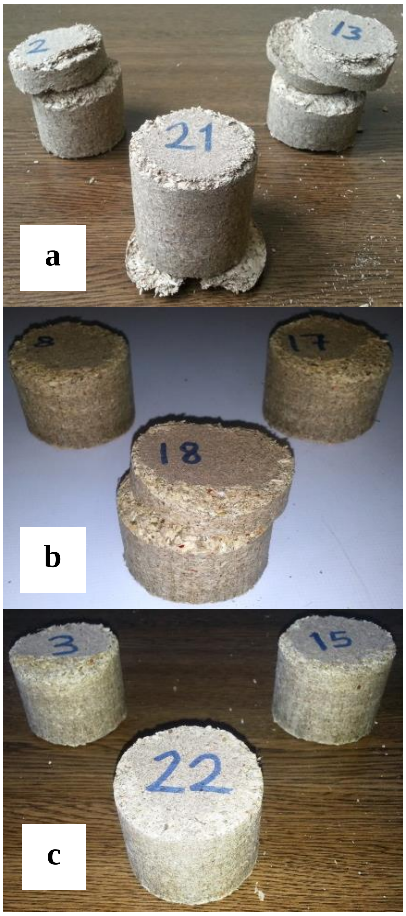

Figure 6 Views after shatter testing briquettes produced at 115 MPa (a), 150 MPa (b) and 185 MPa (c) compaction pressure

As seen in Figure 6, while some breakings were occurred for all of the briquettes obtained at 115 MPa, there was breaking for only one of briquettes formed at 150 MPa, and there was no any breaking in the briquettes obtained by 185 MPa compaction pressure. At the end of shatter testing for the briquettes obtained at 115 and 150 MPa, since pieces broken were on the sieve with 20 mm opening, they were not considered as loss. Thus, the shatter resistances of them were very high. As in tumbler resistance, for all briquettes, the losses were composed from crumbled parts from the top corners of all briquettes.

Tumbler and shatter resistance of briquettes is a significant parameter for transportation and storage, and feeding the combustion systems and to remain solid until the combustion of all briquettes. According to the results of tumbler and shatter tests, the resistances of the briquette are evaluated between 0-1. When briquettes score is higher in tests, say between 0.5-1.0, such results are more difficult to interpret (Eriksson and Prior, 1990). But, the quality of the briquettes increases as they are closer to one (1) value. According to the above information c n the Table 2 are examined, it can be said that sınce the tumbler and especially shatter resistance of all briquettes, are very close to one (1) value, they are strong briquettes. The effect of compaction pressure on both tumbler and shatter resistance of briquettes was found very important, and it increased with increasing compaction pressure.

The results regarding the tumbler and shatter resistances of briquettes were parallel to the ones in the studies carried out by Karaosmanoğlu (2000), Yaman et al. (2000), El Saeidy (2004), Wilaipon (2009), Suhartini et al. (2011), Akman and Bilgin (2012), Gado et al. (2014) for different biomass materials.

Briquettes are negatively affected when they are exposed to excess moisture or rain regardless of length of the period. Inherent binders (lignin) and most externally added binders are water-soluble. This results in one of the weakest points in briquette quality, which is that briquettes must not be subjected to water or humid air. Therefore, the determination of water resistance and equivalent moisture content is extremely important. As seen in Table 1, there was no any result obtained from briquettes related to water resistance, because they disintegrated completely, losing briquette characteristics, in the 27 ℃ water in less than 30 seconds (Figure 7).

Figure 7 View of pepper crop briquette after water resistance test

It was observed that the briquettes were not affected by ambient humidity when they were kept at 20 ℃ and in humidity of 50% for 21 days, and the humidity resistance values were found to be considerably close for all compaction pressure. Moreover, the briquettes produced at all compaction pressures was packed in hermetically, and kept at 20 ℃ and in humidity of 50% for 21 days, and at the end of 21th day, it was observed that there was no change in mass and sizes of the briquettes. The results of water and humidity resistance show that briquettes have to be stored packed and under covered ambient conditions.

As a result, this type materials causing major environmental pollution can be briquetted for utilization as a solid biofuel, and burned in stoves and boilers for household and greenhouse heating.

4 Conclusions

The results obtained from the research are summarized below as follows;

- The pepper crop residues can be briquetted in high-quality without binder.
- The density of briquette increased with an increase in compaction pressure, and the highest density was 1075 kg/m^3.
- The mechanical strength of briquettes increased with the increase of briquetting pressure.
- Briquettes disintegrated in a short time in water.
- Briquettes were not affected by ambient humidity when kept in closed environment conditions
- The losses that might occur in both storing and transporting could be prevented with the packaging the briquettes very well.
- The briquettes can be burned in stoves and boilers for household and greenhouse heating.

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