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PHYSICAL-MECHANICAL PARAMETERS OF HAZELNUT HUSK BIO-BRIQUETTES PRODUCED BY A HORIZONTAL PRESSING BRIQUETTING MACHINE

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Abstract: Türkiye has a big potential of hazelnut residues, especially the husks that is not used for any purposes. It is estimated that 200.000 tons of husk residue is produced per year after hazelnut harvesting. Biomass became very popular since it is alternative source of energy and provides employment facilities in rural areas. Briquetting is the most widely used waste compaction technology. A hydraulic type briquetting machine with horizontal course was manufactured to convert this particular idle residue into biofuels. Some physical and mechanical properties of briquettes produced under different pressures with different particle sizes and having differ-ent moisture contents were determined.

Keywords: Hazelnut, Residue, Biomass, Briquetting

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1. Introduction

Biomass is the second biggest source of primary energy on the world after coal and petroleum, and more than half of the world's population uses this energy (Bapat, et al., 1997; Öztürk and Ekinci, 2016). Biomass defined as different materials of biological origin mainly plant material and animal wastes (Sampson, et al., 1993; Trebbi, 1993), used primarily as domestic energy source is naturally abundant and present a renewable energy opportunity that could serve as an alternative to fossil fuel. Considerable work has been conducted on the use of energy in agri-culture with respect to efficient and economic use of energy for sustainable production (Öztürk, 2016). Comprehensive studies have been performed on energy use in different agri-cultural products (Ahmad et al., 1991; Bobobee, 1992; Dash and Das, 2000; Elbatawi and Mohri, 1999; Hetz, 1992; 1998; Joshi et al., 1992; Mahapatra et al., 2003; Singh and Singh, 1992). Utilization of agricultural residues is often difficult due to their uneven and trouble-some characteristics (Gürdil et al., 2014). The process of compaction of residues into a product of higher density than the original raw material is known as densification. Densification has aroused a great deal of interest in developing countries all over the world lately as a technique for upgrading residues as an energy source (Bhattacharya, et al., 2002). Briquetting is the most widely-used waste compaction technology (Biath and Ondruska, 2012). High-density, compressed biomass simplifies the logistics of handling and storage, improves biomass stabil-ity, facilitates the feeding of solid biomass fuels into energy utilization devices and offers higher energy density, cleaner burning solid fuels that in some cases can approach the heating value of coals (Klass, 1998).

The objective of study is to develop and manufacture a farm scale hydraulic briquetting ma-chine with horizontal pressing course in order to convert agricultural residues into energy materials. For this reason, one of the most important agricultural products of Türkiye the hazelnut residues were used in this research. Briquetting parameters for hazelnut husks were deter-mined under two different briquetting pressures (80 MPa and 160 MPa) with two different particle sizes (2 to 5 mm and 7 to 10 mm) and at M10(8-10%), M12(12-15%) moisture con-tents.

Materials and Methods

A hydraulic type briquetting machine (Figure 1) with a horizontal pressing course (Figure 2) manu-factured for briquetting the hazelnut husk residues. Briquetting pressure range of this machine is adjustable from 0 to 320 MPa by a manometer on it. The pump of the machine has a tank of 25 dm^3 capacity of hydraulic oil with a 1.2

$m^3.s^{-1}$ flow rate. Stroke of the piston is 310 mm and the velocity of the stroke is adjusted to 10 mm.s-1. Machine dimensions are 1280×1155×740 (A×B×C) mm (Figure 3). Operation of the machine is controlled by a start-stop button embedded on it. Hydraulic pump functions by a 15 kW powered 3-phase electrical engine with a star delta starter. The mold for the briquette was not heated. As a support block for the pressing a rectangle shaped metal plate is placed at the end of the course having 125×105×30 mm dimensions. Movement of this plate is done manually.

Figure 1 Hydraulic type briquetting machine.

Figure 2. Horizontal pressing course.

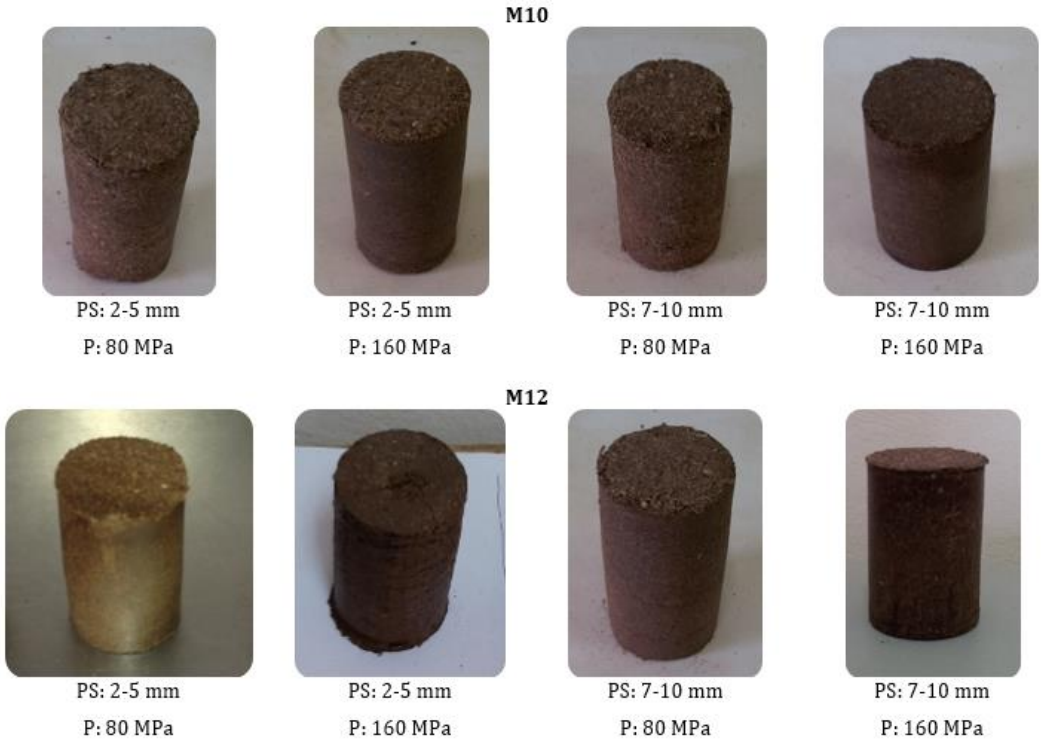

Figure 3. Briquettes produced from hazelnut husks.

The residues were first dried in normal conditions under the sun and their moisture contents were decreased down to 8-10 %. Then the dried material was ground by a knife-hammer mill till the required particle sizes were obtained (2-5; 7-10 mm). Their moisture contents were con-trolled again and they were briquetted under 80 and 160 MPa briquetting pressures.

The chosen briquetting pressure showed that the briquettes were enough solid and durable both physically and in shape. This working pressures also matches with the studies defined in Križan et al. (2015), Zhang and Guo (2014) and Sun et al. (2014). Feeding of material was done batch wise during the briquetting process in order to avoid occlusion. The material prepared for briquetting was poured into the cylindrical mold and they were squeezed by a piston in the mold and the briquettes were obtained. Full cylindrical shape briquettes having 50 mm diameter and 80 to 110 mm varying lengths were produced by this process.

Results and Discussion

The physical-mechanical properties of the briquettes are given in Table 1. The highest briquette volume mass achieved (1198.56 ± 2.89 kg.m-3) at 160 MPa with 2-5 mm particle size, whereas the lowest was achieved at 80 MPa with 7-10 mm particle size (962.18 ± 2.20 kg.m-3). The results showed that briquette volume mass were significantly affected by briquetting pressure and particle size ($P<0.01$). Tumbler index is an indicator of resistance of briquettes against the forces they face during loading, discharging, transporting procedures. Thus it is an indicator of solidness of briquettes (Zhang and Guo, 2014; Niedziolka, et al., 2015). Shatter Index tests the resistance of bri-quettes against impacts during loading and discharging processes. Tumbler and Shatter index-es of briquettes increased with increases in briquetting pressure and decreased with increases in particle size.

Physical mechanical parameters of hazelnut husk briquettes at M12 are given in Table 2. The highest Tumbler Index (91.96 ± 0.22) was achieved at M12 briquettes with 2-5 mm parti-cle sizes at 160 MPa briquetting pressure whereas the lowest was 44.7 ± 1.00 % achieved at 80 MPa briquetting pressure with the material having 7 to 10 mm particle size in M10 bri-quettes. The difference between the Tumbler Indexes of the briquettes at different briquetting pressures was found to be statistically significant ($P<0.01$). The results of Tumbler Index tests showed that the main abrasion and breakdowns realized at the both ends and at the middle part of the briquettes. The reason for that can be the batch squeezing procedure depending on the material feeding which ends up with layered structure. The breaking mainly occurred in that layer borders.

The difference between the Shatter Indexes of the briquettes at different briquetting pressures was found to be statistically significant ($P<0.01$). The tests showed again that all the breakings and split ups happened at the both ends and in the middle of the briquettes due to batch squeezing of the material. The highest and lowest Shatter Indexes were 97.58 ± 0.35 % and 76.20 ± 3.80 % achieved at M12-160 MPa briquetting pressure with 7-10 mm particle size and at M10-80 MPa briquetting pressure with 7-10 mm particle size, respectively.

After all the tests the physical-mechanical parameters of the briquettes produced under 160 MPa briquetting pressure and with two different particle sizes at both moisture contents were found to be suitable for hazelnut husk agricultural residue according to the standards given in EN 14961-1, EN 14961-2 and EN 15210-2.

Converting the available and unused agricultural residues into energy sources is important. Because, this process would eliminate agricultural wastes without harming the environment and it will contribute to the economy of the country since it has potential to create employ-ment opportunities in rural areas (Demirel ve Gürdil, 2014). Besides, when considering the total heating value potential of hazelnut husk residue that is 1,278,405 GJ (Karaca and Gürdil, 2017) in Black Sea Region in Türkiye this huge idle amount of energy must be converted to energy source in benefit of farmers or people living in rural areas.

Table 1. Physical mechanical parameters of hazelnut husk briquettes at M10

M (%)	P (MPa)	PS (mm)	Briquette volume mass (kg.m^{-3})	Tumbler Index (%)	Shatter Index (%)	Water intake capacity, (%) (2 min)	Air moisture resistance (%)
8-10	80	2-5	1012.79 ± 1.51	60.18 ± 0.76	83.04 ± 3.11	37.00 ± 0.57	5.90 ± 0.10
		7-10	962.18 ± 2.20	44.7 ± 1.00	76.20 ± 3.80	40.11 ± 0.88	7.88 ± 0.56
	160	2-5	1198.56 ± 2.89	84.88 ± 0.69	91.65 ± 1.13	27.59 ± 1.09	7.06 ± 0.22
		7-10	1159.04 ± 2.91	83.75 ± 0.59	95.08 ± 0.91	48.18 ± 1.43	5.62 ± 0.14

M= moisture content, P= pressure, PS= particle size

Table 2 Physical mechanical parameters of hazelnut husk briquettes at M12

M (%)	P (MPa)	PS (mm)	Briquette volume mass (kg.m^{-3})	Tumbler Index (%)	Shatter Index (%)	Water intake capacity, (%) (2 min)	Air moisture resistance (%)
12-15	80	2-5	1115.39 ± 1.51	78.72 ± 1.76	95.82 ± 2.14	48.00 ± 0.40	6.68 ± 0.14
		7-10	950.12 ± 2.20	75.6 ± 1.02	86.23 ± 2.90	52.21 ± 0.78	7.89 ± 0.42
	160	2-5	1041.46 ± 6.19	91.96 ± 0.22	95.20 ± 1.13	17.02 ± 0.39	0.76 ± 0.26
		7-10	1031.07 ± 6.25	88.65 ± 0.55	97.58 ± 0.35	12.72 ± 0.32	1.93 ± 0.09

M= moisture content, P= pressure, PS= particle size

Conclusions

In this study a particular hydraulic type briquetting machine with a horizontal course was de-signed and developed for the briquetting of hazelnut husk agricultural residues in order to be evaluated as solid biofuel. Effect of different particle sizes (2-5 mm and 7-10 mm), moisture contents (M10 and M12) were analysed on the physical-mechanical parameters of briquettes which are produced under 80 MPa and 160 MPa pressures by horizontal pressing. The results showed that the horizontal pressing by hydraulic type briquetting machine is very suitable for briquetting of hazelnut husk agricultural residues and especially at 160 MPa briquetting pres-sure at both moisture contents when the physical-mechanical parameters are concerned. These kinds of researches will help to improve the design and function of briquetting machines for the future and by this way for the energy deficiency of the world by converting agricultural residues to energy sources.

Author Contributions

Concept: B.D. (50%) and G.A.K.G. (50%), Design: B.D. (50%) and G.A.K.G. (50%), Supervision: B.D. (50%) and G.A.K.G. (50%), Data collection and/or processing: B.D. (50%) and G.A.K.G. (50%), Data analysis and/or interpretation: B.D. (50%) and G.A.K.G. (50%), Literature search: B.D. (50%) and G.A.K.G. (50%), Writing: B.D. (50%) and G.A.K.G. (50%), Critical review: B.D. (50%) and G.A.K.G. (50%). Submission and revision. All authors reviewed and approved final version of the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

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