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ANALYZING SOME RELATIONSHIPS BETWEEN PHYSICAL-MECHANICAL AND THERMAL PARAMETERS OF BIO-BRIQUETTES PRODUCED FROM PERSIMMON PRUNING RESIDUES

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Abstract: Turkey imports a considerable part of its energy means from abroad. This creates a huge burden on the national economy. Turkey can be considered as poor in fossil fuel resources, but rich in renewable energy sources. Biomass is one these renewable energy sources which comes from various agricultural production lasting whole year due to four seasons richness of the climate in Turkey. In this study, solid cylindrical briquettes produced from persimmon tree pruning wastes under 2 different moisture contents (12% - 15%), with 3 different particle sizes (3-5-8 mm) and under 4 different briquetting pressures (80 - 120 - 160 - 200 MPa) were analyzed for its solid fuel properties. The lowest lower heating value was found as 18.50 MJ/kg where the highest lower heating value was 18.90 MJ/kg. The lowest ash content was obtained as 1.73% at 15% moisture content, 3 mm particle size under 200 MPa briquetting pressure while the highest was 2.47% at 12% moisture content, 5 mm particle size under 120 MPa briquetting pressure. The relationships between some physical-mechanical and thermal parameters of the produced briquettes were also analyzed.

Keywords: Briquette, Energy, Agricultural waste, Solid bio-fuel, Persimmon pruning

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1. Introduction

Energy is of great importance for our country as it is in the world. Energy is a necessity needed by humanity in order to live a modern life. Where, how and at what costs this need is met is a fundamental factor that determines the way that countries gain superiority over each other today. Countries rich in energy resources make large amounts of financial, technological and military investments in order to protect their existing energy resources, and countries with insufficient energy resources to access energy resources. In addition, the proximity of a country to energy resources and hosting energy corridors means that the strategic position of that country and its bargaining power in the international arena increase (Yılmaz, 2012).

Turkey, when analyzed in terms of overall energy use 78% and of fossil fuel sources and its derivate 92% dependent to foreign sources. For this reason, it has a risky economical structure even effected by tiny fluctuations in energy markets (Acar et al, 2016). Thus, the current account deficit highly affects by this uncertain fluctuation. The search for new energy sources has gained a big momentum considering that existing fossil fuels will run out in the near future. The increasing need for energy and the search for new energy resources has increased the importance of renewable energy sources.

Renewable energy sources are; solar energy, wind energy, geothermal energy, biomass energy, wave energy, hydraulic energy, tidal energy, hydrogen energy, etc. are resources that are constantly available and cannot be consumed (Özalp, 2019). The industrialization efforts of developed countries and developing countries, the developments in technology and the gradual increase in the population have caused a rapid increase in energy need and thus in energy prices. When examined from the perspective of our country, it concentrates on resources such as natural gas and the big stress posed by international forces led by price increases on the economy, is a major problem in Turkey's development (Demirel ve Gürdil, 2018).

Despite being a poor country in terms of fossil fuels sources Turkey has advantage of having four seasons throughout the year that makes her rich in renewable energy sources. Renewable energy sources are an endless source of energy. One of the most important features of them is that they help to protect the environment by reducing carbon dioxide emissions. Besides, they contribute to the decrease dependency on abroad in energy and decrease in unemployment with the increase of various job opportunities. Biomass as one of the renewable energy sources, should be taken into account due to its residual potential in recent years. It is an important factor in preventing environmental pollution, too (Demirel ve Gürdil, 2018). According to 2014 data, agricultural production is carried out in approximately 20-21 million hectares of land in our country. Approximately 60 million tons of residue and waste produced just from crop production. However, it is estimated that 15-20 million tons of this amount can be used as biofuel raw material (Acar ve ark, 2016).

For example, cultivated areas in the Black Sea region constitute 20% of the region. Tea, hazelnut, paddy, corn, wheat, sunflower and various fruits are the leading products. A significant amount of renewable and non-fossil-based solid fuel can be obtained from the wastes of these products such as; straw, stalk, hazelnut or rice husk, pruning residues etc. Thus, waste that is left to the environment, burned randomly and not economically utilized will be evaluated as pellet fuel and contribute to the economy of the region (Dok, 2014).

Biomass energy is the largest primary energy source in the world after coal and oil, and more than half of the world's population uses biomass as the primary energy source (Öztürk and Ekici, 2016). Biomass is defined as the source of organic matter that is the origin of living organisms and is formed as a result of green plants' storage by converting solar energy into chemical energy through photosynthesis. Within the scope of biomass energy technology; wood (energy forests, wood residues), oilseed crops (sunflower, rapeseed, soy, safflower, cotton, etc.), carbohydrate crops (potato, wheat, corn, beet, etc.), fiber crops (flax, hemp, hemp, sorghum, etc.), plant wastes (branches, stalks, straw, roots, bark, etc.), animal wastes, and urban and industrial wastes are evaluated. Biomass is a strategic energy source that can be renewed, can be grown anywhere, provides socio-economic development, environmentally friendly, fuel for vehicles and also electricity can be produced from that and can be obtained. Biomass is used in energy technology by directly burning or by increasing the fuel quality through various processes, and producing alternative biofuels (easily transportable, storable and usable fuels) with properties equivalent to existing fuels. Many liquid, solid or gaseous biofuels are obtained from biomass by physical processes (size reduction-crushing and grinding, drying, filtration, extraction and aggregation) and transformation processes (biochemical and thermochemical processes) (Karaosmanoğlu, 2006). For example, wastes generated as a result of tree pruning in orchards and in vineyards and wastes in forest areas are collected in one place and burned or left to decompose. Using modern biomass energy will be very useful the country’s economy and for the minimization of environmental pollution.

2. Materials and Methods

This work is carried out in the laboratories of Ondokuz Mayıs University Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering. Persimmon pruning waste is used as a material. The wastes were dried down to 12-15 % moisture content under natural conditions. The material was first ground with a hammer mill and the particle sizes were reduced to 3mm, 5mm and 8mm (Figure 1). The ground material was then briquetted with no adhesive material inside with a hydraulic type briquetting machine under 80, 120, 160 and 200 MPa pressures (Figure 2). The specific mass of the material before briquetting varied between 140-150 kg/m^3.

Figure 1. Ground material.

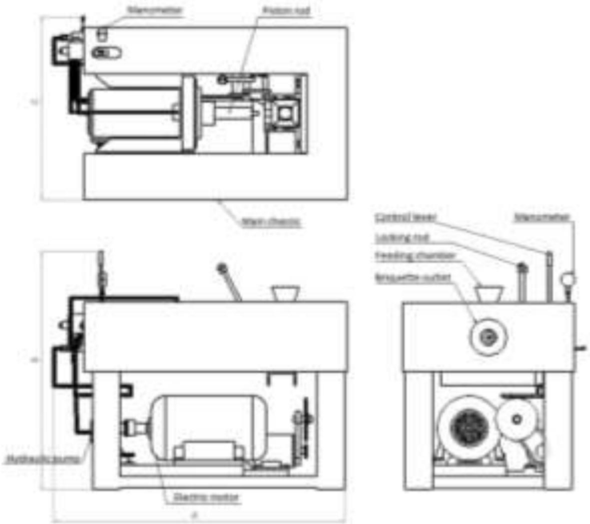

Figure 2. Hydraulic briquetting machine (A: 1280 mm; B: 1155 mm; C: 740 mm).

The density of the briquettes was determined by stereometric method and varied between 950-1115 kg/m^3. Storage and transportation costs of materials can be reduced after compression. The lower calorific values of the samples were determined using a calorimeter device according to the EN 14918 standard. The ash content of the materials was determined according to the EN 14775 standard. The mechanical durability (tumbler index) test of the briquettes was performed according to the EN 15210-2 standard. For shatter resistance of the briquettes, the briquettes were weighed and recorded before the test. Then the briquettes were dropped 10 times from a certain height (1-1.8 m) on a solid ground and their weight was recorded again. Shatter resistance was then calculated as a percentage (%) of mass loss.

In order to test the suitability of the measured values to the analysis of variance, the normality analysis was performed with the Kolmogorov-Smirnov single-sample test, and it was determined that the data had a normal distribution (P> 0.05) and the variance homogeneity was evaluated with the Levene test and the variances were homogeneous (P> 0.05). Then it is understood that variance analysis can produce reliable results. Duncan multiple comparison test was used to compare the means. Analyzes were made in SPSS 20.0 software with OMU license. Trials were carried out in three replications.

3. Results and Discussion

Persimmon pruning wastes first chopped by axe then dried down to 12-15% moisture content and grinded to 3 mm, 5 mm, 8 mm particle sizes, and then it was briquetted in a hydraulic type briquetting machine under 80, 120, 160 and 200 MPa pressures. Briquette density, firmness, lower heating values, ash content of the briquettes were determined.

The below works are done:

- Thermal properties were compared with some other fossil fuels.
- Relations between briquetting pressure and briquette density were analyzed.
- Relations between briquetting pressure and firmness were analyzed.
- Relations between briquette density and firmness were analyzed.
- Relations between briquette density and ash contents were analyzed.

Relations between the analyzed variables were evaluated and also expressed in graphs. Best fit in the curves were obtained with linear equation 1 as follows.

$$y=ax+b \quad (1)$$

3.1. Comparison of Heating Value and Ash Contents

Lower heating values and ash contents of the briquettes are given in Table 1 and 2. Ash content and heating value of some other fossil fuels are given in Table 3.

Average heating value and ash content of briquettes at 12% moisture content are 18.69 MJ/kg and 2.28%, respectively. Those values were 18.64 MJ/kg and 1.89% at 15% moisture content. The heating values of the briquettes are said to be compatible with some other fossil fuels. They were higher than brown coal and wood, but lower than other coals, fuel oil and diesel fuel (Table 3). From this point of view, it can be concluded that the produced briquettes can be used as solid biofuel also keeping in mind that the briquettes have higher heating value than the wood (2500 cal/g) (Gürdil et al., 2014).

It's also seen that the briquettes had lower ash contents than some of the selected fuels (Table 3.) This is also a good indicator for a biofuel material. It is considered that briquettes produced from pruning wastes can be used as an alternative energy source in solid fuel combustion systems in terms of their thermal values and ash contents.

Dok et al. (2014) in their research on finding suitable mixture values for pellet production from some agricultural wastes with high energy value, revealed that agricultural wastes can be used by making pellets or briquettes in every area where coal is used, either alone or by mixing them. Besides, considering that 90% of lignite coal mined in our country has a calorific value below 3000 kcal/kg (Dok, 2014), it can be said that agricultural wastes are a quality fuel source. For example, paddy stalk and paddy husk, which have the lowest calorific value among the wastes obtained from field crops, are around 3500 kcal/kg. As can be seen, the calorific value, moisture content, ash and flue gas emission values of agricultural wastes are of higher quality than lignite coal, so can be used instead of coal.

Table 1. Lower heating values and ash contents at 12% moisture content

PS (mm)	P (MPa)	LHV (MJ/kg)	AC (%)
3	120/160	18.73	2.20
5	120	18.71	2.47
8	200	18.63	2.17

PS= particle size, P= pressure, LHV= lower heating value AC= ash content.

Table 2. Lower heating values and ash contents at 15% moisture content

PS (mm)	P (MPa)	LHV (MJ/kg)	AC (%)
3	200	18.90	1.73
5	200	18.53	1.85
8	200	18.50	2.10

PS= particle size, P= pressure, LHV= lower heating value AC= ash content.

Table 3. Heating values and ash content of some fuels (Erdoğmuş et al., 2016)

Material	LHV (MJ/kg)	AC (%)
Hazelnut husk residue	17.72	10.65
Soma coal	23.03	27.3
Zonguldak coal	25.54	14.3
Brown coal	11.51	19.10
Fuel oil	40.61	0.1
Diesel	42.70	<0.01

LHV= lower heating value (MJ/kg), AC= ash content (%).

3.2. The Effect of Briquetting Pressure on Briquette Density

The effect briquetting pressures (80, 120, 160 and 200 MPa) on briquette densities concerning the different particle sizes (3, 5 and 8 mm) and moisture contents (12 and 15%) are given in figure, below.

When the graphs are examined:

- Briquetting pressure and briquette density values showed linear variation at both moisture contents.
- When the R2 values for both moisture values compared, it is seen that the 12% moisture values are higher.
- When the graphs formed by briquette pressure and briquette density values for both moisture values are examined, it is seen that the curves for 5mm grinding fineness of 12% moisture are higher.
- For the graphs at 12%;
- All the curves showed a polynomial fluctuation and briquetting densities varied between 700 and 1600 kg/m3.
- The highest briquette densities depending on briquetting pressure recorded at 5 mm particle sized briquettes.
- The equations of the curves showed a reliable relation due to high R2 values.
- For the graphs at 15%;
- Best fit for the curves achieved at linear function and briquetting densities varied between 700 and 1000 kg/m3.
- The highest briquette densities recorded at 5 mm particle size.
- The equations of the curves showed a reliable relation due to high R2 values.

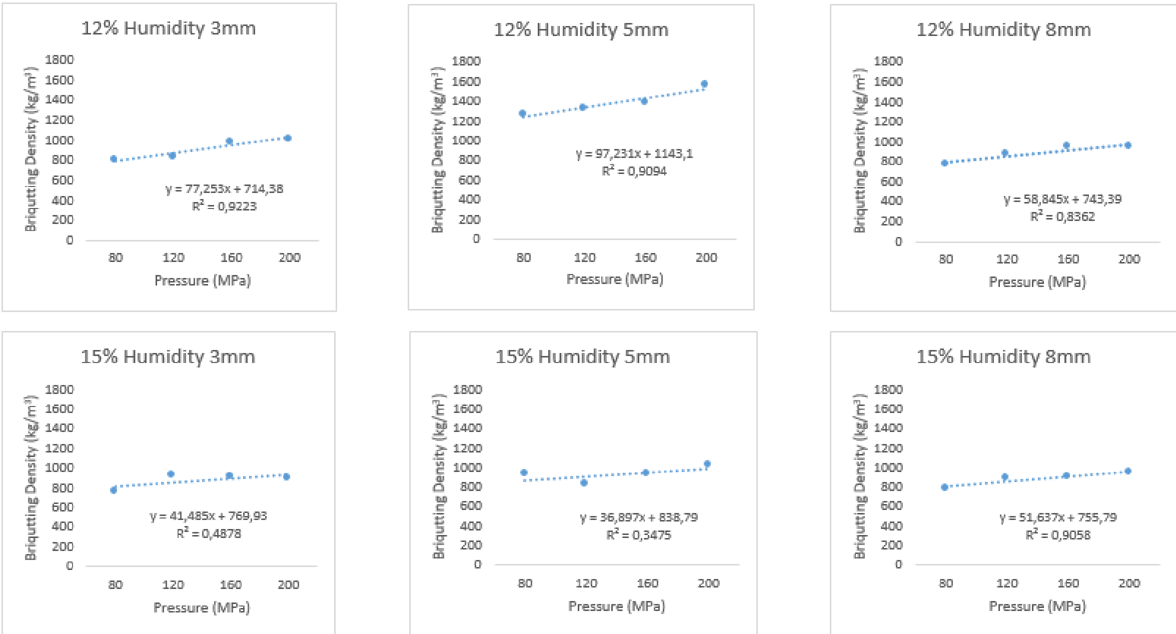

Figure 3. Effect of briquetting pressure on briquette density

3.3. The Effect of Briquetting Pressure on Firmness

The effect briquetting pressures (80, 120, 160 and 200 MPa) on firmness values of the briquettes concerning the different particle sizes (3, 5 and 8 mm) and moisture contents (12 and 15%) are given in Figure 4.

When the graphs are examined:

- Briquetting pressure and firmness values showed a linear variation at both moisture contents, that firmness values increased when the briquetting pressures increased.
- Firmness values changed in between 500 and 6000 N at all samples. The briquettes produced with 12% moisture content had higher firmness values than the ones at 15%.
- Highest firmness value was obtained at 12% moisture content with 5 mm particle size where the lowest was at 15% moisture content with 3 mm.

3.4. The Effect of Briquette Density on Firmness

The effect of briquette density obtained at different briquetting pressures on firmness values of the briquettes concerning the different particle sizes (3, 5 and 8 mm) and moisture contents (12 and 15%) are given in Figure 5.

When the graphs are examined:

- There was a linear relation between briquetting density and firmness values of the briquettes.
- The briquettes produced with 12% moisture content had higher firmness values than the ones produced with 15%.
- Highest firmness value was obtained at 12% moisture content with 5 mm particle size where the lowest was at 15% moisture content with 3 mm.

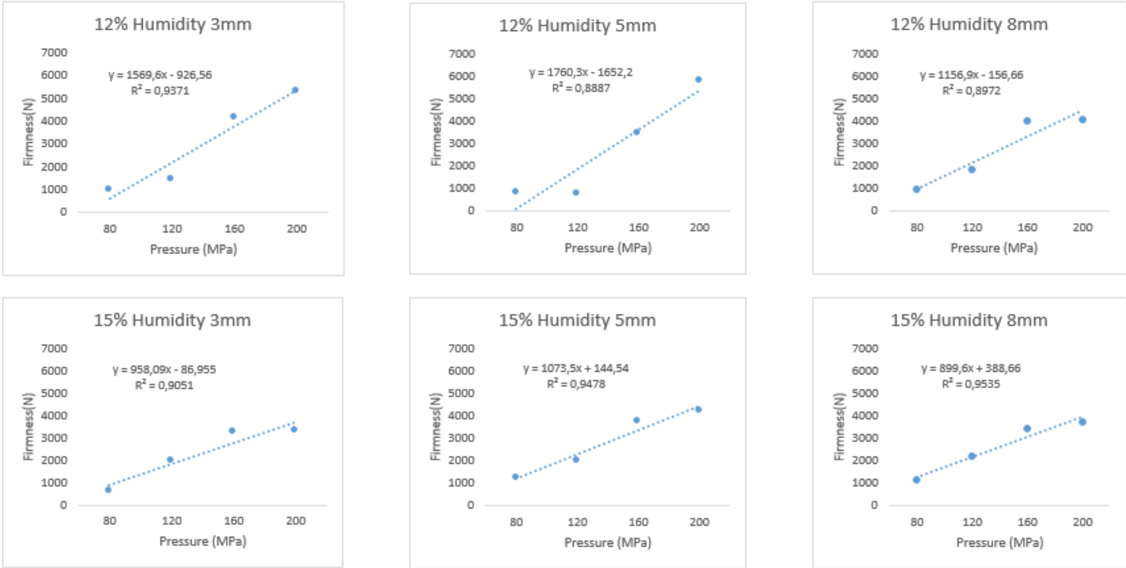

Figure 4. Effect of briquetting pressure on firmness

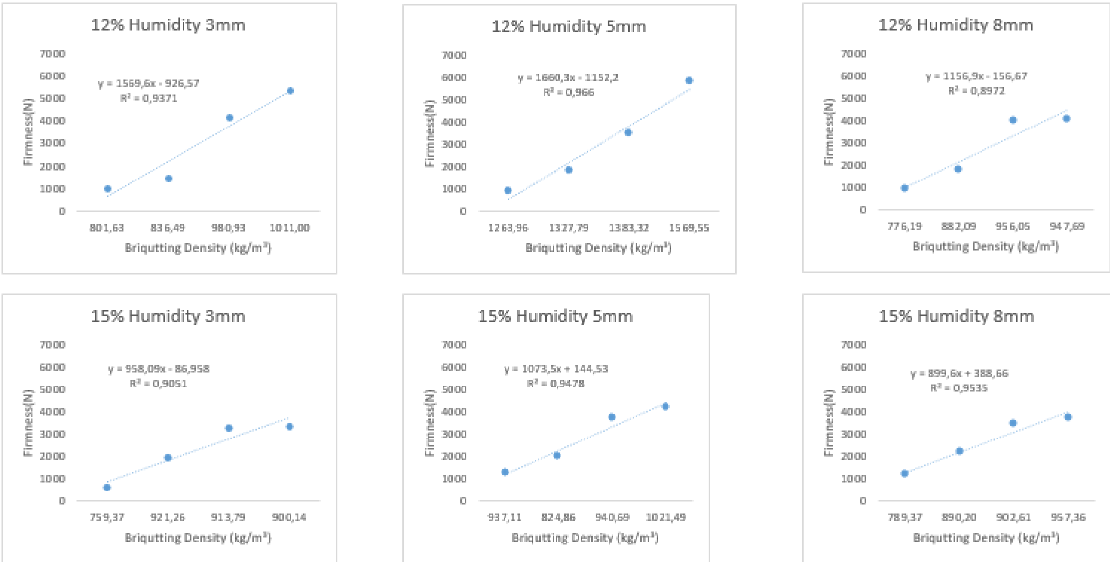

Figure 5. Effect of briquette density on firmness

3.5. **The Relation Between Briquette Density and Ash Content**

The relations between briquette densities obtained at different briquetting pressures and particle sizes under two different moisture contents and their ash contents after burning were examined. The results showed that they had a polynomial relationship between each other and the parameters of their equation are given below in Table 4 and Table 5.

When the relations between the analyzed variables were evaluated and expressed in graphs. Best fit in the curves were obtained with second degree polynomial equation 1 as follows.

y=ax^2+bx+c (1)

Table 4. Parameters of equations at 12%

PS (mm)	a	b	c	R^2
3	0.025	-0.221	2.7	0.90
5	0.1875	-0.9665	3.7175	0.94
8	-0.1875	0.7665	2.1325	0.95

PS= particle size

Table 5. Parameters of equations at 15%

PS (mm)	a	b	c	R^2
3	0.1575	-1.0205	3.3425	0.88
5	-0.1	0.48	1.535	0.98
8	-0.3825	1.9275	0.5825	0.85

PS= particle size

Conclusion

Solid cylindrical briquettes produced from persimmon tree pruning wastes under 2 different moisture contents (12% -15%), with 3 different particle sizes (3mm-5mm-8mm) and under 4 different briquetting pressures (80 - 120 - 160 - 200 MPa) were analyzed for its solid fuel properties. The lowest lower heating value was found as 18.50 MJ/kg where the highest lower heating value was 18.90 MJ/kg. The lowest ash content was obtained as 1.73% at 15% moisture content, 3 mm particle size under 200 MPa briquetting pressure while the highest was 2.47% at 12% moisture content, 5 mm particle size under 120 MPa briquetting pressure. Relations between briquetting pressure and briquette density, briquetting pressure and firmness, briquette density and firmness, briquette density and ash contents along with their thermal properties were analyzed. As a result, the briquettes produced from pruning wastes of persimmon orchards can be accepted as an alternative solid bio-fuel source.

Author Contributions

Concept: G.A.K.G. (50%) and B.D. (50%), Design: G.A.K.G. (50%) and B.D. (50%), Supervision: G.A.K.G. (50%) and B.D. (50%), Data collection and/or processing: G.A.K.G. (50%) and B.D. (50%), Data analysis and/or interpretation G.A.K.G. (50%) and B.D. (50%), Literature search: G.A.K.G. (50%) and B.D. (50%), Writing: G.A.K.G. (50%) and B.D. (50%), Critical review: G.A.K.G. (50%) and B.D. (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.

References

Acar M, Gizlenci Ş, Dok M, Erdoğmuş M, Çelik A. 2016. Bazı tarımsal atık-artıkların biyokütle kaynağı olarak değerlendirilmesi. 2. Ulusal Biyoyakıtlar Sempozyumu, 27-30 Eylül, Samsun, Türkiye, pp. 27-30.

Demirel B, Gürdil GAK. 2018. Fındık zurufu atığından yakıt briketi elde edilmesi ve brikete ait bazı özelliklerin belirlenmesi. Anadolu J Agr Sci, 33(1): 24-29.

Dok M. 2014. Karadeniz Bölgesinin tarımsal atık potansiyeli ve bunlardan pelet yakıt olarak yararlanılması. Enerji Tarımı ve Biyoyakıtlar, 4: 28-29.

Dok M, Gizlenci Ş, Acar M, Çelik AE, Erdoğmuş M. 2014. Enerji değeri yüksek bazı tarımsal atıkların pelet üretimi için en uygun karışım oranlarının belirlenmesi. 2. Ulusal Biyoyakıtlar Sempozyumu, 27-30 Eylül, Samsun, Türkiye, pp. 93-100.

EN 14775. 2013. Solid biofuels - Determination of ash content. European Committee for Standardization: Management Centre, Avenue Marnix 17, B-1000 Brussels. https://standards.iteh.ai/catalog/standards/cen/05d820de-8dca-4180-b45b-8e4ca0973f6c/en-14961-2-2011 (accessed date: July 23, 2022).

EN 14918. 2013. Solid biofuels - Determination of calorific value. European Committee for Standardization: Management Centre, Avenue Marnix 17, B-1000 Brussels. https://standards.iteh.ai/catalog/standards/cen/05d820de-8dca-4180-b45b-8e4ca0973f6c/en-14961-2-2011 (accessed date: July 23, 2022).

EN 15210-2. 2013. Solid biofuels - Determination of mechanical durability of pellets and briquettes - Part 2: Briquettes. European Committee for Standardization: Management Centre, Avenue Marnix 17, B-1000 Brussels. https://standards.iteh.ai/catalog/standards/cen/05d820de-8dca-4180-b45b-8e4ca0973f6c/en-14961-2-2011 (accessed date: July 23, 2022).

Erdoğmuş M, Gizlenci Ş, Acar M, Dok M, Çelik A. 2016. Bazı tarımsal atıklardan briket üretimi üzerine araştırmalar. 2. Ulusal Biyoyakıtlar Sempozyumu, 27-30 Eylül, Samsun, Türkiye, pp. 335-342.

Gürdil GAK, Demirel B, Acar M, Dok M. 2014. Samsun'da tarımsal faaliyetler sonucu açığa çıkan bazı tarımsal atıklardan elde edilen briketlerin özellikleri, Enerji Tarımı ve Biyoyakıtlar 4. Ulusal Çalıştayı Bildiriler Kitabı, 28-29 Mayıs, Samsun, Türkiye, pp.123-130.

Karaosmanoğlu, F. 2006. Dünyada enerjiye duyulan ihtiyaç ve alternatif enerji kaynaklarına yöneliş. Türkiye'nin Enerji Stratejisi Ne Olmalıdır, 1: 9-19.

Özalp M. 2019. Küresel ölçekte Türkiye'nin enerji arz ve talep güvenliği. Electron Turkish Stud, 14(1): 537 -552.

Öztürk H, Ekinci K. 2016. Türkiye'de biyokütleden elektrik üretimi: Mevcut durum ve beklentiler, 2. Ulusal Biyoyakıtlar Sempozyumu, 27-30 Eylül, Samsun, Türkiye, pp. 17-26.

Yılmaz A. 2012. Türkiye'de sektörel enerji tüketimini etkileyen faktörler ve alternatif enerji politikaları. Doktora Tezi, Adnan Menderes Üniversitesi, Sosyal Bilimler Enstitüsü, İktisat Ana Bilim Dalı, Ikt-Dr-2012-0001, Aydın, pp. 295.