The Utilization of Hazelnut Shell (*Coryllus Avellana* L.) Residues as Compressed Combustible Fuel

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Abstract

In this research, we have studied some opportunities for using hazelnut shells (*Coryllus avellana* L.) as compressed combustible fuel in the context of biomass material. A pellet mill was used during the production. The physical and chemical characteristics of the material obtained were subjected to various combustion, calorie and chemical tests. The calorific value of the obtained compressed material and the standby time in its glowing state was improved. We have determined that such charcoal, made from hazelnut shells, has characteristics similar to another coal made from wood timber and can be used in similar ways.

Keywords: Hazelnut shell, compressed combustible fuel, physical and chemical characteristics.

Fındık Kabuğunun (Hazelnut Shell) Sıkıştırılmış Yakıt Olarak Değerlendirilmesi

Özet

Bu çalışmada Odun Dışı Orman Ürünleri kapsamında biyokütle kaynaklarından fındık kabuklarının (Coryllus avellana L.) sıkıştırılmış yakıt malzemesi olarak değerlendirilme olanakları araştırılmıştır. Pellet değirmeni kullanılarak sıkıştırılmış yakıt materyalinin üretimi yapılmıştır. Elde edilen malzemenin fiziksel, kimyasal özellikleri ile çeşitli yanma, kalori ve kül testleri yapılmıştır. Fındık kabuğundan elde edilen sıkıştırılmış biyokütle materyalin özellikle mangal kömürü olarak değerlendirilebileceği ve diğer odunlardan elde edilen mangal kömürü yakıtı ile elde edilen ısıl değerlere yakın özelliklerde olduğu belirlenmiştir.

Anahtar Kelimeler: Fındık kabuğu, sıkıştırılmış yakıt, fiziksel ve kimyasal özellikler.

Introduction

Agricultural residues are excellent alternative materials as substitutes for wood because they are plentiful, widespread, and easily accessible. Aside from their abundance and renewability, the utilization of agricultural residues has advantages for the economy, environment, and technology. Due to the rapid increase in the need of energy source, more people start to become interested in small scale wood pellet plant and briquette plants. They want to turn environmental wastes into pellet fuel. Biomass fuel pellets are made from agricultural waste and are a replacement for fossil fuels such as oil or coal, and can be used to heat boilers in manufacturing plants, the home, and also have applications in developing countries. Biomass briquettes are a renewable source of energy and avoid adding fossil carbon to the atmosphere.

Almost any biomass can be briquetted. Briquetting plants or wood pellets are using the following biomass to make briquettes: saw dust, bamboo dust, bagasse, cotton stalk, coffee husk, groundnut shell, straw, mustard husk/stalk, pine needles, rice husk, sugar mill waste, jute waste, coir pith. Plus other wastes and residues like castor shell, tobacco stem, tea waste, sander dust, tree bark, wild grasses and shrubs and sander dust etc. can be also be briquetted individually or in combination without using any binder. Briquettes are a good substitute for, or can be used with, coal, lignite, firewood and offer numerous advantages.

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Hazelnut shells are generally used as an alternative heating source in cities and suburban areas of the Eastern and Western Black Sea Regions of Turkey, where most of the nuts are grown and harvested. Since hazelnut shells burn so quickly, they immediately turn into ash, and thus, it is not possible to use the heat produced by them efficiently. Moreover, a small explosion occurs during the initial flashing of coal gas, which is emitted during the lighting of the stove. Therefore, such a situation may result in small accidents with stoves.

The cultivated hazelnut (*Coryllus avellana* L.) is native to the Black Sea coast of Turkey, where almost 65-70 % of the world's hazelnuts are produced (Mennan et al., 2006). Hazelnut shell is an important agricultural residue, and the amount produced annually in Turkey is estimated to be about 3 x 10^5 tons (Demirbaş, 2002). The shells have no economic value and are either burned or left in the field after the harvest.

Demirbaş (1999) investigated hazelnut shells and the derived charcoal were densified to briquettes using pyrolytic oil or tar as binder. Briquette properties improved with an increase in briquetting pressures and percentages of binder materials. The best charcoal briquettes were obtained at 800 MPa pressure at 400 K.

In this research, we have studied the production and usage of compressed combustible material from the hazelnut shells. We have examined this material to see whether it is compatible with being used as a practical combustible fuel, especially as a compressed one like the coal used in stoves or braziers. Charcoal is widely used for outdoor grilling and barbeques in backyards and on camping trips. Biomass fuel pellets are replacement for fossil fuels such as oil or coal. Therefore, the aim of this study was to investigate the potential utilization of hazelnut shells pellet production for use as a combustible fuel.

Materials and Methods

During the production of the compressed combustible material, hazelnut shells were obtained from a nut-cracking factory located in the Düzce Region. Commonly, nuts which are separated from their nutshells are sorted according to size and put on the market as foodstuff. The nutshells remaining after the above mentioned processes are packaged in 50 kg bags to be used as an alternative heating material. A pellet mill was used for the production of the compressed biomass fuel from the nutshells and other added materials.

The hazelnut shells were ground prior to the compression process. The ground hazelnut shells were granulated and reduced in size to 1-4 mm. A pellet mill with the dimensions of 30 cm in length and 2.5 cm in width was selected to facilitate the desired formation of the briquettes.

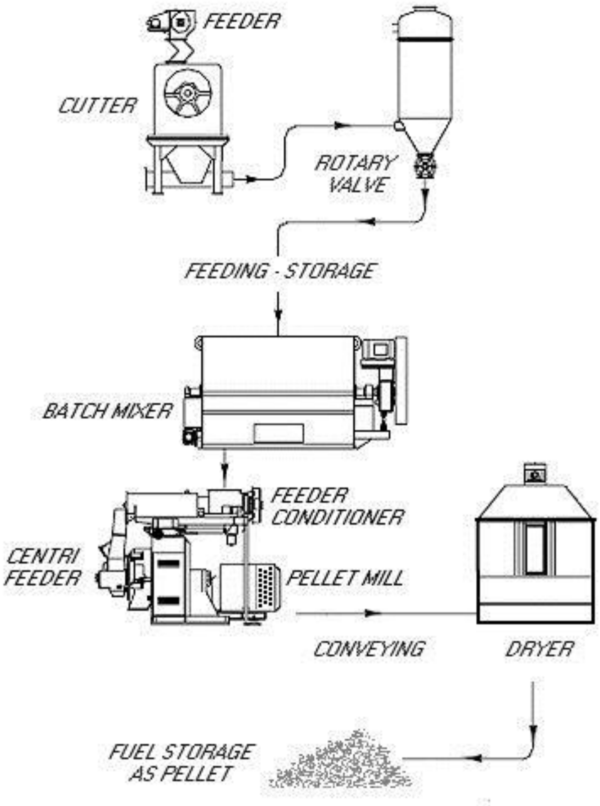

Figure 1. Pellet mill and the process for the production of compressed hazelnut shell combustible fuel.

After the hazelnut shells were ground into smaller pieces, as shown in Figure 1, they were transferred to a silo (storage facility). Then, this mixture, in powder form, was transferred through the supply unit to the mixing tank, and stirred in the presence of hot vapor, after the addition of appropriate adhesives (starch, approximately 5 %). The resulting heated mixture was pushed through the pellet mill by means of the supply unit. This material, having a temperature of 80°C, and a humidity of 25 %, was then exposed to a pressure of 4.5 atmosphere. After coming out pellet mill, the compressed product was sent to combustible dehydration unit and packed into 2 and 3 kg bags.

Results

The chemical properties of the hazelnut shells were determined and specimens were sampled and prepared according to Tappi standard (Tappi 257, 1985). Holocellulose and cellulose contents were determined according to the chloride method (Wise and Karl, 1962). The lignin (Tappi 222, 1998) and ash (Tappi 211, 1993) contents were also studied. Alcohol-benzene (Tappi 204, 1997), cold and hot-water (Tappi 207, 1993) and 1 % NaOH (Tappi 212, 1998) solubilities were determined. The results for the test are listed in Table 1.

Table 1. The chemical composition of hazelnut shells (current study), hazelnut husks, cereal straw and soft/hardwoods (Çöpür et al., 2007).

Raw Material	Chemical Composition (%)				Solubility (%)			
	Holo-cellulose	α-cellulose	Lignin	Ash	Alcohol benzene (2/1)	1% NaOH	Hot water	Cold water
Hazelnut shells*	57.5 (0.50)	27.1 (0.01)	40.4 (0.16)	1.71 (0.02)	0.50 (0.04)	33.7 (0.86)	5.99 (0.07)	3.55 (0.11)
Hazelnut Husks	55.1	34.6	41.4	8.23	2.0	50.4	20.9	18.2
Cereal Straw	64-71	35-39	12-17	3.12	2-4	38- 40	12-17	4 -7
Hardwoods	70-78	45-50	30-35	0.35	2-6	14 -20	2-7	4 -6
Softwoods	63-70	45-50	25-35	0.35	2-8	9-16	3-6	2 -3

*Values in parentheses are the standard deviations of the means; the results are averages of 4 samples.

The calorific value of the obtained coal in air-dried form was 4582 kcal kg^{-1}, while its standby time in a glowing state was 48 minutes. Table 2 shows the results of the analyses of the total ash content, total volatile components, sulfur content in ash, total sulfur and upper and lower calorific values.

Table 2. The results of the analysis of combustible compressed hazelnut shells.

Analysis Types	Original Samples	Air-dried Samples	Analysis Method
Total Ash (%)	2.27	-	TS ISO 1171 (2006)
Essential material (%)	72.40	80.88	TS 711 ISO 562 (2002)
Sulfide in Ash (%)	0.05	0.06	ASTM D5016 (2002)
Total sulfide (%)	0.15	0.17	ASTM D4239 (2002)
Bottom Calorie (kcal kg^{-1})	3788	4300	TS ISO 1928 (2006)
Top Calorie kcal kg^{-1})	4101	4582	TS ISO 1928 (2006)

Table 3 shows the elemental analyses (the content of carbon, hydrogen, and nitrogen) in the dried samples, air-dried samples, and samples without ash.

Table 3. The results of elemental analysis of combustible compressed hazelnut shells.

Elemental Analysis	Original samples (%)	Air dried samples (%)	Samples without ash (%)
Carbon	44.49	48.04	51.47
Hydrogen	4.81	5.20	5.57
Nitrogen	1.42	1.53	1.64

Discussion

The intended advantages of the material obtained by compressing hazelnut shell pellets include: facilitation of transportation due to the reduced volume of the material achieved by compression, a slower initial ignition time but longer sustained heating period, and the elimination of the explosion effect due to accumulating gasses. When the hazelnut shells are compressed, the volume density is three times less. This compressed material is similar to other fuel and similar calorie values are maintained. In light of these findings, we have concluded that hazelnut shells can be compressed in pellet mills and effectively used in fireplaces, braziers, and stoves as a compressed combustible fuel.

Table 4. Some lignocelluloses and annual plant waste heat values compared with hazelnut shells.

Plant	Heat values*	
	MJ kg^{-1}	Kcal kg^{-1}
Hazelnut shells	18.36	4388
Bark	22.80	5449
Wheat Straw	18.03	4309
Phragmites australis	19.29	4610
Populus nigra	18.24	4359

*Calculated air-dried for calorie (1 mega joule = 239 kcal).

A comparison made between the current study, using hazelnut shells, and other studies using hazelnut husks (Çöpür et al., 2007), cereal straw (Eroğlu, 1988), and soft and hardwoods (Sjostrom, 1993) indicated that the holocellulose content of hazelnut shells was close to that of the other crop residues and wood species (Table 1). The lignin content was higher than cereal straw, but it was similar in hazelnut husks. The alcohol-benzene solubility of hazelnut shells was lower than that of the other crop residues. The 1 % NaOH and hot water solubility was higher than the wood species and lower than other crop residues. Table 4 shows the heat values of wood and annual plants (Yalınkılıç et al., 1997; Güler and Akgül, 2002). Similar results were obtained for hazelnut shells, annual plant waste and the wood.

Conclusions

The results achieved showed that hazelnut shells which are processed in a pellet mill can be used advantageously as a combustible material. The most important point here is that this material has less volume than other combustibles and has improved burning characteristics. Along with the decrease in the volume of the material, the transportation costs are reduced. In addition, development in the areas of nutshell sales and usage is promoted. Moreover, no explosion or flashing was observed during the burning process. While the average heating value of normal nutshells is 4388 kcal, the upper and lower limits of the compressed material have been determined as 4300 – 4582 kcal.

Several binders may be used to positively affect the adhesion. However, adherents which may result in an increase in toxic components were not included in this study since we only examined ways to use nutshells as coal.

The heating value of compressed hazelnut shells was increased to an upper limit of around 194 kcal. Although no other change was observed in the calorific values, the time period when this combustible was in a glowing state was significantly increased. While normal hazelnut shells with the same weight burn and turn into ash in seven minutes, the compressed combustible charcoal glows for 48 minutes. This shows that the calorific value of nutshells can be used as a regular long-term heating source. Since nutshells comprise a common biomass, it is possible to achieve high-capacity mass production.

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