Monika Smaga
Research and Innovation Centre Pro-Akademia
9/11 Innowacyjna Street, 95-050 Konstantynów Łódzki, Poland, monikaturek@op.pl

QUALITY PARAMETERS OF THE SOLID FUEL PRODUCED FROM COFFEE GROUNDS AND TEA GROUNDS

Abstract
The article describes quality parameters of coffee grounds and tea grounds, as main components of a potential sustainable fuel. Samples were tested to determine the calorific value, humidity content, amount of sulfur and ash produced in the subsequent process. The research has shown that biomass consisting of coffee and tea grounds may become a high-energy, sustainable solid fuel. Additionally, the possibility of producing pellets from such materials has been tested and a suitable binder, which would allow forming granules of appropriate size, has been selected.

Keywords
Pellet, Biomass, Coffee grounds, Tea grounds, Quality parameters

Introduction

The EU countries are the greatest consumers of solid sustainable fuels as the heating demand in this region is growing every year. For European manufacturers of such fuels it is obviously a good news, however high demand also results in competition growth. Therefore, desirable fuel needs to have good quality parameters, apart from competitive price. These parameters can be certified, but pellets certification is optional. Therefore, many manufacturers of solid fuels make use of only one certificate of conformity with EN 14961-2, which may be issued based on product samples delivered to the lab [1-6].

Solid sustainable fuels are usually produced in a form of granules called pellet. Pellet is a fuel material made of dried and compacted wood waste such as sawdust, woodchips and bark or energy plants [1-3]. Pellet is a kind of a good-quality briquette, having form of granules, in the shape of spheres or cylinders, in size of a few centimeters. Due to its composition, pellets have a calorific value similar to wood (15.00-19.00 MJ / kg), low humidity (<10.00 %), low sulfur content (<1.00 %), and produce a small amount of ashes (<1.00 %). These attributes make them a convenient fuel to use in the individual boilers and stoves that are equipped with reservoir, dispenser and feeder. It appears that the majority of pellets available on the market consist only of timber originating from sawmills or from energy plants that are intended for this purpose. Pellet can also be produced from straw, but such pellet produces more ashes than pellets from wood (3-5 %), which forces users to clean and service their boilers and stoves more frequently. Additionally, straw pellets require some changes in the pelleting line, for example standard matrix in pellet mill needs to be replaced by the matrix dedicated for straw. Also other types of biomass can be used dried and compacted in order to produce pellet [1-3].

The biomass can be defined as the entire organic matter that exists on Earth, all materials of plant or animal origin which are biodegradable. This includes waste or residues of biological origin from agriculture, forestry, fisheries and from other related industries, as well as cereal grains that do not meet the relevant quality requirements and other wastes from food industry [7,8].

Biomass is described by many laws and regulations, both in Polish and European law. Some legal acts define also the difference between the biomass and other waste, because biomass is often mistakenly treated as a waste. Biomass is not a waste because it is environmental friendly and it can be, for example, used for producing energy, fertilizers or can be added to animal fodder. The biomass, consisting entirely of organic material is fully degradable and does not pollute the environment [9].

Biomass has been long used for obtaining a solid sustainable fuel, often in the form of pellets, which burn well, have relatively high calorific value and low humidity content. Production of such fuels does not necessarily require any additional chemicals. Pellets are formed by drying and compressing biomass in special pelleting

lines equipped with a pellet mill (pellet press), which is a type of mill/press used to create pellet granules [10-14].
Pellet produced from biomass is an alternative fuel or so-called agropellet. There are no standards for describing quality parameters of agropellet. It is clear that such pellet will have worse quality parameters than pellet produced from wood but it turns out that it can be suitable for some energy purposes [2].

Biomass and its components are not hazardous. Biomass does not contain any harmful chemicals, it is environmental friendly, because it consists of organic matter of plant or animal origin. Furthermore, it turns out that agropellet can be a solution for eliminating most of biowaste from the environment and using it as a component for biofuels. The biowaste is: mowed grass, timber logging waste, waste from orchards (fruits and wood cutting) or fruit and vegetables farming wastes, such as peels or seeds. It also includes grass, straw, branches, peels from fruits, vegetables and mushrooms, nutshells, weeds, fallen leaves, etc. All kinds of mentioned biowaste, in accordance to the law, can be, and often is, used for producing pellet. It appears that there are various kinds of biowaste, mainly from food industry, that may be turned into high calorific heating fuel. Coffee grounds and tea grounds are good examples of biowaste that are currently treated as worthless waste that has to be disposed. However, theoretically it may be possible to use such waste to produce agropellet [10,11, 15-18].

Research part
The study material consisted of samples from:

- coffee grounds
- black tea grounds
- green tea grounds
- white tea grounds
- red tea grounds

Grounds in each sample consisted of a mixture of the same species of coffee or tea. However, a single sample could consist of products from different manufacturers. In the first stage of the study, samples were dried (for 5 hours at 105°C) in a laboratory oven. Afterwards, the quality parameters, used for describing solid fuels, were measured. The aim of the study was to determine the quality parameters of the coffee grounds and tea grounds, including calorific value, in order to confirm whether such biomass is suitable as a component for producing pellets or other form of solid biofuels.

The procedure undertaken for measuring calorific value (Lower heating value) of the fuel involves measurement of the following parameters for each tested sample:

- humidity content
- content of hydrogen
- Higher heating value

Following formula has been used to calculate the Lower heating value:

$$LHV = HHV - r*(a*h + w) \text{ [MJ/kg]}$$

LHV – Higher heating value
HHV – Lower heating value
r – heat of vaporization of water (2,455 MJ/kg)
a – hydrogen to water conversion rate 8,94
h – hydrogen content [kg]
w – humidity content [kg]

Additionally, percentage content of sulfur and percentage content of ashes left after combustion were determined.

Tests have been carried out on 3 different measuring devices:

- Calorimeter (Parr 6400 CALORIMETER) – Higher heating value
- Thermogravimetric Analyser (TGA ELTRA THERMOSEPT) – humidity, ashes
- Carbon Hydrogen Sulphur Determinator PC Controlled (ELTRA CHS 580) – sulfur, hydrogen

Tests have been carried out at room temperature (ca 25^{o}C). Each measurement was carried out in three repetitions. It was assumed that tested material has a high calorific value, but it may also have a higher content of sulfur in comparison to wood pellets and thus can produce more ash after combustion.

Table 1. Averaged quality parameters of the tested materials

No.	Tested material	Lower heating value [MJ/kg] (after drying)	Humidity [%] (after drying)	Ash content [%]	Sulfur content [%]
1.	Coffee	21.15	6.40	1.25	0.35
2.	Black tea	19.50	5.81	2.35	0.32
3.	Green tea	19.39	5.74	2.48	0.26
4.	White tea	18.20	5.67	2.32	0.28
5.	Red tea	18.76	5.63	2.34	0.10

Source: Author's

Each sample was examined 3 times and the averaged results are shown in the Table 1. Research of coffee grounds and tea grounds in terms of fuel quality parameters has clearly indicated that production of good-quality pellets from such biomass components is possible.

Calorific values of examined samples were between 18.20 and 21.15 MJ/kg (after drying). It means that all tested materials do not differ significantly from the wood pellets that are currently available on the market. In case of coffee grounds, the calorific value is even higher than that of wood pellets. As samples were pre-dried before examination, they met the humidity requirement standard for wood pellets. Drying of components is one of the steps of pellets production in pellet mills, so humidity value of examined samples should be consistent with the humidity of pellet produced from examined material.

The research showed that the tested biomass contains sulfur in amount that meets criteria of the standards for wood pellets. Besides, the presence of sulfur is a natural consequence of sulfur content in the vegetable, which are a building material of tested biomass [1,19].

The main disadvantage of tested materials compared to wood pellets is a high content of ash. The ash content in the biomass above 1% may result in faster clogging of heating boiler tubes and stoves. However, ash content at the level between 1 and 3% may not be a significant issue as long as boiler is equipped with ash handling device, i.e.; grate.

The possibility of forming pellets from coffee grounds and tea grounds was also examined. The study was conducted in a laboratory condition. Pellet granules were produced by the manual press using Parr Pellet Press. The research demonstrated that production of pellets from the dried coffee grounds and tea grounds requires usage of binder, because tested materials failed to stick together. Unlike wood pellets, tested materials contained no natural resin, which is a natural binder. Instead, starch was used. Starch is commonly used as a binder for the pellets produced from material other than timber.

Studies have shown that the addition of starch in the amount of 0.1% allows material binding and forming granules of pellet from coffee grounds and tea grounds. It follows that, in order to produce one ton of such pellets, an addition of 1 kg of starch is required. In pelleting lines, starch is mixed with biomass material, and then the mixture is pressed and heated, which results in forming of pellets.

Granules of pellets, produced by the manual press from coffee grounds (Figure 1) and from black tea grounds (Figure 2), with addition of starch as a binder, are shown in the pictures below.


Fig. 1. Pellets made of coffee grounds with addition of starch as a binder
Source: Author's


Fig. 2. Pellets made of black tea grounds with addition of starch as a binder
Source: Author's

Of course the starch is not the only binder that could be used to produce such pellet. It is possible to use other natural binders such as various types of resins or vegetable oils.

Summary

The tested material derived from coffee grounds and tea grounds has similar quality parameters to wood pellets available on the energy market. Regarding their calorific value and humidity they are equal to wood pellets, while ash content is slightly higher than that in branded wood pellets available on the market.

The necessity of using additional binder which helps to form a pellet from coffee and tea grounds may be troublesome. However, it is possible to use natural binders such as resin or starch proposed in this study. Natural binders are not harmful to the environment, therefore pellet from coffee grounds and tea grounds can still be considered as a sustainable pellet.

Moreover, such biomass can be used for producing composite pellets. In other words, various types of mixtures can be created. Coffee and tea grounds can be combined in suitable proportions with other components, such as wood or coal dust, which should result in creation of a good quality pellet. Choosing relevant ingredients and mixing them in adequate proportions allow adjustment of calorific value and humidity content, as well as of ash.

Perhaps such pellet could be used for energy production in the nearest future to solve the problem of organic waste disposal from cafes or restaurants and to contribute to the field of sustainable energy [16,20-23].

References

[1] Wood pellets standard EN 14961-2

[2] I. Olszyńska, Pellety drzewne i ich certyfikacja, Magazyn Biomasa, Rynek Pelletu, September 2016

[3] J. Morell, K. Hill, All About Pellet Stoves. This Old House Magazine, 2012

[4] E. Hughes, Biomass co-firing: economics, policy and opportunities, Biomass Bioenergy 2000, 19, 457-65

[5] J.M. Jones, A.R. Lae-Langton, L. Ma, M. Pourkashanian, A. Williams, Pollutants generated by combustion of solid biomass fuels, Springer Verlag London 2014.

[6] P. Samaras, G. Skodras, G.P. Sakellaropoulos, M. Blumenstock, K.W. Schramm, A. Kettrup, Toxic emission during co-combustion of biomass-waste wood-lignite blends in an industrial boiler, Chemosphere 2001, 43, 751-755.

[7] E.D. Lavric, A.A. Konnov, J. De Ruyck, Dioxin levels in wood combustion – a review, Biomass Bioenergy 2004, 26, 115-145.

[8] B. Schatowitz, G. Brandt, F. Gafner, E. Schlumpf, R. Bühler, P. Hasler, T. Nussbaumer, Dioxin emissions from wood combustion, Chemosphere 1994, 29, 2005-2013.

[9] G. Wielgosiński, Termiczne przekształcanie odpadów komunalnych – wybrane zagadnienia, DOOSAN, Racibórz, 2016

[10] G. Wiśniewski, M. Pisarek, Energetyczne wykorzystanie drewna i słomy. Możliwości i doświadczenia praktyczne w: Wykorzystanie odnawialnych źródeł energii na szczeblu lokalnym. Conference materials, Poznań – Kraków – Warszawa, 1999

[11] T.Golc, Energetyczne wykorzystanie biomasy, poprzez spalanie i zgazowywanie, Instytut Energetyki, Instytut Badawczy, Warszawa, 2014

[12] A. Musialik-Piotrowska, W. Kordylewski, J. Ciołek, K. Mościcki, Characteristics of air pollutants emitter from biomass combustion in small retort boiler, Environment Protection Engineering 2010, 36, 123-131.

[13] A. Demirbas, Hazardous Emissions from Combustion of Biomass, Energy Sources, Part A 2008, 30, 170-178.

[14] C.K.W. Ndiema, F.M. Mpendazoe, A. Williams, Emission of pollutants from a biomass stove, Energy Conversion and Management 1998, 39, 1357-1367.

[15] Czy warto segregować? Mechaniczno-biologiczna przeróbka odpadów komunalnych, Przegląd Komunalny, November 2004

[16] R. Zarzycki, Energia z odpadów, PAN Łódź, Komisja Ochrony Środowiska, Łódź, 2008

[17] S.V. Vassilev, D. Baxter, L.K. Andersen, C.G. Vassileva, T.J. Morgan, An overview of the organic and inorganic phase composition of biomass, Fuel 2012, 94, 1-33.

[18] B. Schatowitz, G. Brandt, F. Gafner, E. Schlumpf, R. Bühler, P. Hasler, T. Nussbaumer, Dioxin emissions from wood combustion, Chemosphere 1994, 29, 2005-2013.

[19] J. Berg, J.L. Tymoczko, L. Stryer, N.D. Clarke, Z. Szweykowska-Kulińska, A. Jarmołowski, H. Agustyniak, Biochemia, PWN, Warszawa, 2007

[20] M. McDermott, Biomass Can Only Offer Major Emission Reductions if Best Practices Are Followed, New UK Report Says, 2009

[21] E.A. Sondreal, S.A. Benson, J.P. Hurley, M.D. Mann, J.H. Pavlish, M.L. Swanson, Review of advances in combustion technology and biomass cofiring, Fuel Processing Technology 2001, 71, 7-38.

[22] S.G. Sahu, N. Chakraborty, P. Sarkar, Coal-biomass co-combustion: An overview, Renewable and Sustainable Energy Reviews 2014, 575-586.

[23] D.A. Tillman, Biomass cofiring: the technology, the experience, the contribution consequences, Biomass and Bioenergy 2000, 19, 365-384.