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Research article

Co-pelletization of sewage sludge and agricultural wastes

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A B S T R A C T

This paper concerns the process of production and properties of pellets based on biomass wastes. Co-pelletization was performed for sewage sludge from municipal wastewater treatment plant and other biomass material such as animal and olive wastes.

The aim of the present study was to identify the key factors affecting on the sewage sludge and agricultural residues co-pelletization processes conditions. The impact of raw material type, pellet length, moisture content and particle size on the physical properties was investigated. The technic and technological aspects of co-pelletization were discussed in detail.

The physical parameters of pellets, i.e.: drop strength, absorbability and water resistance were determined. Among others, also energy parameters: low and high heat value, content of ash and volatiles were presented.

Results showed the range of raw materials moisture, which is necessary to obtain good quality biofuels and also ratio of sewage sludge in pelletizing materials.

The analysis of the energetic properties has indicated that the pellet generated on the basis of the sewage sludge and another biomass materials can be applied in the processes of co-combustion with coal. Those biofuels are characterised with properties making them suitable for use in thermal processes and enabling their transport and storage.

1. Introduction

Biofuels, defined as those produced through contemporary, renewable biological processes rather than by geological ones, will be crucial to the future of global power supply together with other renewable energy sources, such as solar and eolic. All these are expected to significantly contribute to the decrease of air pollutants and GHG emissions in the atmosphere. Overall, biomass is foreseen to contribute to half of the EU renewable energy targets, as laid out in the Renewable Energy Directive (RED) (EU, 2009). Sources of biofuels can be, among the others, agricultural residues, sewage sludge, waste from vegetable and animal origin. Biofuels generation can be at the local level, by direct onsite digestion/co-digestion of organic matter, with biogas production (Capodaglio et al., 2016a; Callegari et al., 2013), or in more complex facilities offsite, where biomass can be processed, for example, by pyrolytic or other processes (Tańczuk et al., 2017; Capodaglio et al., 2016b) to generate liquid biofuels that can be more easily handled. While biomass characteristics influence the resulting biofuel properties (Capodaglio and Callegari, 2017), underlying regulations and incentives are paramount for their expanding diffusion and economic sustainability (Capodaglio et al., 2016c). The EU in fact estimates to achieve a 14% share of biofuels by 2020, with the objectives to reduce oil dependency and GHGs emissions (Raboni et al., 2015).

This paper deals with the process of production and properties of pellets from biomass wastes, a topic often neglected but that has a significant market, especially in rural areas in Turkey.

1.1. Agricultural residues

By-products from agricultural production may be e.g. straw, seed and cereal shells, remains of fruit processing and animal excrements.

It is estimated that over three billion tonnes of agricultural residues were generated world-wide (Werther et al., 2000). The types of agricultural by-products depend on the location of the site in the world. For instance, Europe takes the first place in the production of straw from cereals (wheat and barley) while the highest

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share in the global agricultural discard balance belongs to rice husks (around 43%), which are produced by Asian countries (Werther et al., 2000).

Turkey is a country that has great agricultural potential with 23.07 million ha arable land. Total amount of agricultural solid waste is about of 50–65 million tonnes (Acaroglu and Aydogan, 2012). Agricultural activities are concentrated on the production of industrial plants used for example for the production of industrial products such as wheat, barley, maize, cotton, olive and sunflower oils, hazelnut, etc. These food-processing industries produce residues, which could be utilized for energy production.

Table 1 illustrates selected types of agricultural by-products and their composition and energy values.

The breeding and agricultural activity, especially livestock production on an industrial scale, is seen as one of the main sources of natural environment pollution. Depending on the farming system, animal farms generate solid (dung) and liquid (liquid manure) animal excrements.

It is estimated that the available agricultural and animal residues in Turkey can be roughly equal to 22–27% of energy consumption in Turkey (Demirbas, 2008).

Table 2 presents total amount of animal wastes production in Turkey.

In terms of energy production, agricultural products made particularly for that purpose may be used (maize, sugar beetroots, rape, oat and other) as well as unclassified assortments of cereals, i.e. cereals which cannot be used for consumption due to mechanical damage, biological infection or low quality.

The production of energy from biomass should proceed without harm to the production of food. Therefore, agricultural wastes and residues should be ones used for the production of energy in the first place. The potential of agricultural by-products is very high and it seems reasonable to use it for such purpose.

1.2. Sewage sludge

Municipal sewage sludge is waste, which is generated in process of cleaning water in wastewater treatment plants. Amount of it cannot be prevented and reduced according to the requirements regarding the quality of treated sewage. Sewage sludge constitutes the main type of wastes related with sewage treatment and its amount is about 1–2% of volume of treated sewage.

The problem with its neutralisation arises from the amount of generated sludge and its properties. The amount of generated sludge depends on many factors - mainly on the pollutant content in sewage and applied treatment technology.

In Turkey, in 2012 wastewater discharge from sewerage systems per person was 0.182 m^3 per day. The State Statistical Institute has estimated that the population will reach to 90 million by 2025. It is expected that the amount of annually usable water per person may decrease to 1.222 m^3 by the year 2025 (Turkstate, 2012).

According to the results of Municipal Wastewater Statistics Survey in 2012 (Turkstate, 2012), out of 4.1 billion m^3 of wastewater was discharged via sewerage, 3.3 billion m^3 was treated in wastewater treatment plants.

The properties of municipal sewage sludge result in the fact that it is technically difficult to manage it. The fundamental parameter that has an impact on it is high content of moisture. After mechanical dehydration sewage sludge moisture can be reduced down to 65%, only after drying process to 10% (Tańczuk et al., 2016).

The organic compound content in sewage sludge allows for using it in energy production processes. The influence of organic compound content on the calorific value of sewage sludge is widely discussed in the literature (Khan et al., 1995; Thipkhunthod et al., 2006; Stasta et al., 2006; Wherter and Ogada, 1999), where correlations may be found of change of sewage calorific value depending on the degree of fermentation and water content.

Several ranges of calorific values for various types of sewage sludge may be defined: and so for raw sludge the calorific value is 16–20 MJ/kg d.m. (dry mass) and for fermented sludge it drops to 10–15 MJ/kg d.m. and in the case of very well performed fermentation even to 6.3–10.5 MJ/kg d.m. (Wherter and Ogada, 1999; Wzorek, 2012).

Sewage sludge after mechanical dehydration has greasy and semiliquid consistence, which makes mechanical operations more difficult. Hence, it is suggested to use it together with other waste and subject it to the process of pelletization to achieve adequate properties allowing for its easy transport and dosing in thermal processes.

1.3. Technical and technological aspects of the production of pelletized fuels from wastes and biomass

The basic processes employed in processing wastes and biomass into fuels is forming them into bales, briquettes or pellets and also grinding or milling to powder.

Pellets and briquettes are mostly solid cylindrical, differing solely in their dimensions. Briquettes have diameters between 50 and 90 mm and lengths between 75 and 300 mm, while pellet diameters are less than 10 mm with no more than 35 mm length (Nunes et al., 2014).

The array of wastes that may be used in fuel production is very wide. Some types of wastes have properties, which allow for direct combustion without any interference in its properties and physical

Table 1
Characteristics of selected agricultural residues.

Parameter	Moisture %	Ash % d.m.	Volatiles % d.m.	C	H	O	N	S	HHV MJ/kg
				% d.m.					
Corncob[a]	0	6.4	n.d.	45.53	6.15	41.11	0.78	0.13	17.81
Barley straw[a]	15	4.9	n.d	46.8	5.53	41.9	0.41	0.06	18.79
Oats straw[a]	15	4.9	n.d.	46	5.91	43.5	1.13	0.015	18.09
Wheat straw[b]	7.75	6.22	15.68	46.95	5.355	1.05	0.51	0.22	18.5
Grape waste[c]	–	7.5	67.9	50,0	6.0	34.4	2.0	0.1	22.1
Almond shells[c]	–	1.2	79.3	49.2	6.0	43.4	0.2	0	19.7
Sunflower straw[a]	40	3		52.9	6.58	35.9	1.38	0.15	20.82
Olive oil waste[c]	–	7.1	77.3	48.9	6.2	36.2	1.4	0.2	21.6

d.m. – dry mass; n.d. – no data; HHV – Higher Heating Value.
[a] Source: (Skoulou and Zabaniotou, 2007).
[b] Source: (Arvelakis et al., 2001).
[c] Source: (Werther et al., 2000).

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