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Technological conditions for the production of fuel pellets from biogas digestate

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ABSTRACT: The paper deals with the technological conditions optimized for the production of high quality pellets from digestate from biogas plants. Digestate as a by-product of fermentation process is mostly use as a fertilizer in agriculture sector. However, its residual energy potential in dry state is quite high. Drying the digestate is possible by waste heat produced by cogeneration unit usually integrated in biogas plant. The paper describes the treatment of this by-product and its tests of transformation process into high-grade solid biofuel - pellets. Results show optimized technological conditions of the production process with respect to the evaluated physical-mechanical properties of the produced pellets, like bulk density, mechanical durability or hardness. Results of the study prove that the digestate from biofuel plants can be economically transformed into high-grade fuel with excellent mechanical properties. This fact allows high economic efficiency of biofuel plants.

Keywords:digestate, biogas, pellets, pelleting, densification, fuel

I. INTRODUCTION

Agricultural waste represents a high energy potential currently still underused.Nevertheless, it can be used for energy in different ways and in different forms[1,2].Agricultural waste is relatively successfully used for biogas production as a desired renewable energy source in biogas plants.In recent years, biogas plants have become a suitable and welcome source of energy source production.Biogas digestate is a byproduct in biogas plants. Using the dried digestate as solid fuel seems to be apromising alternative.

Laboratory tests of various types of digestate have confirmed that digestate as a waste from biogas production still has a high usable net calorific value from 14 MJ/kg to 15.8 MJ/kg.[1,2]Therefore, it is appropriate to treat it to a high-grade form of fuel in the form of pellets. The high relative humidity of this digestate at the outlet of the fermentation process (especially in dry fermentation) does not usually have to be a problem either.Biogas is mostly used at the place of production by cogeneration units with combined production of electricity and often unused heat, which is ideal for drying the digestate before the pelleting process.Chemical composition and physical properties of digestate fuel pellets depend on the blend of substrates used as feedstock for biogas production. Ash content is between 14.6% and 18.3% and softening temperature between 1090 °C and 1110 °C. [1,3,4]

The field of phytomass densification for energy purposes is still not very well developed. Phytomass is used more often as raw material for gasification. The reason is the different chemical composition of the phytomass, which creates certain restrictions in combustion compared to wood. At present, the production of solid biofuels from phytomass used agricultural waste as a raw material, but also whole crops of cereals (straw together with grain).[5]The ever-increasing interest in producing energy from local sources of agricultural residues poses new challenges for the development of technologies and processes in the production of biofuels suitable both for large and small combustion plants. Agricultural residues represent a cheaper energy source than wood, but their use has some technical limitations [6].However, the phytomass and also the digestate has its advantages from the point of view of producing solid biofuels. High availability and low cost is its economic advantage. The results of scientific studies[5,6,7,8,9] show that the densification process of phytomass and biogas digestate needed significantly lower compacting pressures than dendromass to achieve the same pressings density.

Based on this consideration, the following tests were performed to transform the digestate into a noble storable form of fuel. The aim of the tests was to pellet dry digestate from biogas plants (with possible fraction size adjustment, moisture adjustment and homogenization) into the final product of high-grade pellets for the purpose of their subsequent energy recovery.

II. MATERIAL AND METHODS

2.1 Raw material

The feedstok composition of used digestate consists of maize silage (80%), gras and gras silage (16%) and other agriculture waste (corn cob mix) (4%).The digestate from the biogas plant was delivered with input relative humidity 11.5%. This value of the input moisture of the raw material for the pelleting technology is relatively low, but the used pelleting press KAHL 33-390 also includes a homogenizer with a water nozzle to increase the humidity.However, it could be stated in advance that no further moisture treatment by drying would be necessary.The size of the fraction of the supplied raw material (Fig. 1) was unsuitable for the required pelleting experiments in the form of pellets with a diameter of 6 mm.The fractional composition of the raw material is shown in Figure 2.

Fig. 1 Raw material – untreated digestate

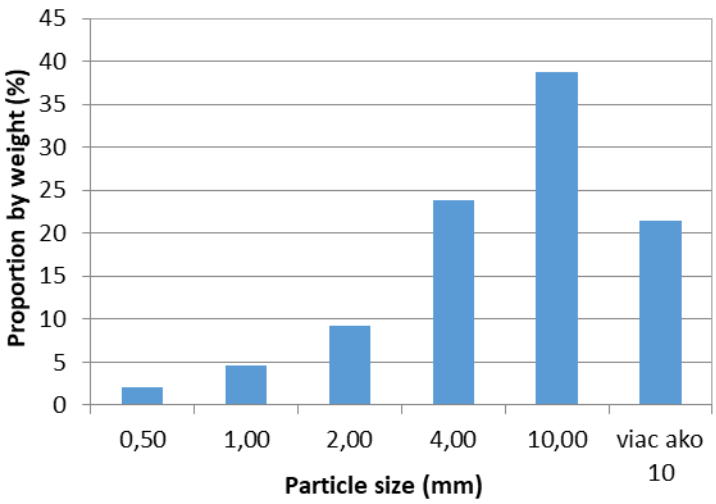

Fig. 2 Particle size distribution of untreated digestate

2.2 Fraction size

Before pelleting the raw material, it was necessary to refine the size of the fraction by crushing.The Stoza SV 5 hammer mill with a sieve with a mesh size ϕ 6 mm was used.The achieved output fraction composition of the digestate is shown in Figure 3 and Figure 4.A treated feedstock with this fraction size proved to be suitable for the production of pellets with a diameter of 6 mm.In the case of the pellets production with a diameter of 8 to 10 mm, it is assumed that refining of the fractional composition by crushing is not necessary.Thus, in the production of industrial pellets with diameters larger than 8 mm, the overall technology would consist exclusively of the degree of pelleting and cooling of the pellets.Energy and investment costs for crushing technology will be eliminated. The energy costs of the pelleting technology decrease significantly with the increasing diameter of the pellets.

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Fig. 3Crushed raw material

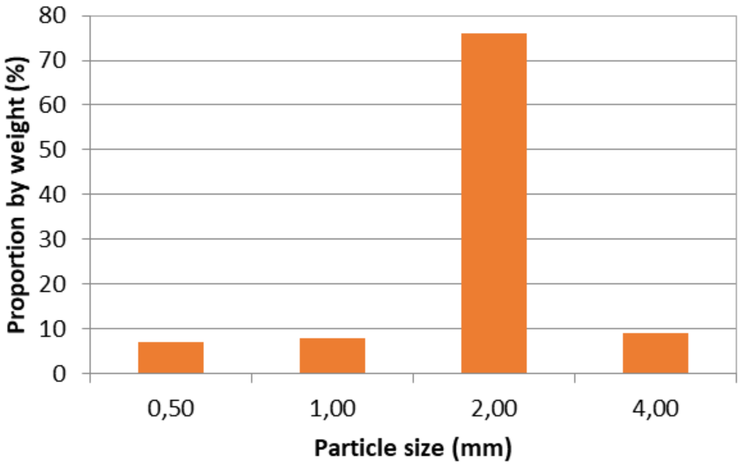

Fig. 4Particle size distribution of crushed digestate

2.3 Moisture content

The moisture content of the supplied digestate was 11.5% measured by gravimetric scales (Fig. 6),after crushing and pneumatic transport it decreased slightly to 11.04%.Before the raw material entered the pelleting press, its moisture content was adjusted to the optimum value by spraying cold water.The value of moisture content was set by the flow meter of the water nozzle located in the homogenizer (Fig. 5).The material for moisture measuring was removed just before entering the pressing chamber of the pelleting machine.With constant dosing of the raw material, the water flow was increased until pellets with the highest mechanical quality indicators were reached.The optimal moisture content value of the material was evaluated as 19.74%.This moisture is surprisingly high, but it should be noted that this is mainly the surface moisture that is necessary in the case of digestate to form strong bonds in the pellet.After pressing the pellets, this surface water evaporated and after 24 hours of stabilization, the pellets showed a satisfactory moisture value of up to 11%.The conclusion from the moisture optimization is, that it is not necessary to dry the digestate to a low moisture content such as 11.5% as delivered.

Fig. 5 Homogenizer of pelleting press with water jet

Fig. 6 Laboratory scales for measuring moisture

2.4 Pelleting process

Experimental tests of digestate pelleting were performed on a KAHL 33-390 pelleting press (Fig. 7).Subsequently, pellet cooling with abrasion separation in the pellet cooler was used (Fig. 8).The technical parameters of the pellet press are given in Table 1.A pelleting die with a geometry of the pressing chambers primarily intended for wood sawdust was used for pelleting.The diameter of the pellets was 6 mm.The use of this matrix (with the appropriate geometry of the pressing chambers) proved to be suitable during the experiments, as evidenced by the high quality of production.

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Fig. 7Used pelletingmachine KAHL 33-390

Fig. 8Used pellet cooler with fines separation

Table 1. Technical parameters of the pelleting press KAHL 33-390

KAHL	**33-390**
Die diameter (mm)	390
Rolls diameter/width (mm)	230/77
Number of rolls	2
Drive - power (kW)/speed (min^{-1})	15-30/1500
Perimeter speedof rolls (m/s)	2.2
Drilled area of the die (cm^2)	617
Weight of machine with drive (kg)	1150

III. RESULTS OF TESTS

3.1 Bulk density of pellets

Bulk density is an important parameter of fuels delivered on a volume basis and, together with calorific value, is used to determine energy density.Bulk density increases with increasing density of solid biofuel.The bulk density is dependent on the particle density and the pore volume. The higher the bulk density the higher becomes their energy density and the lesser are transport and storage costs. Therefore, from an economic point of view, the high bulk density of biofuels is required by biofuel producers, distributors, retailers and, ultimately, consumers.

Bulk density is the ratio of the weight of biofuel poured into a defined volume. It depends on the particle density of the biofuel and the pore volume of the poured biofuel.A rough estimate of the bulk density of the pellets can be determined as half of the biofuel particle density.

The properties that solid biofuels must meet are detailed in ISO 17225-1[10].Bulk density of solid biofuels as one of the basic indicators of their quality is given by the valid standard ISO 17828[11].This standard specifies a detailed procedure for determining the bulk density of bulk solid biofuels that can be transported by a continuous flow of material.The measurement is performed by means of a standardized container with a specific volume (Fig. 9), which is filled with pellets and the bulk density is measured after three impacts of the container from a height of 15 cm.

Measurement and evaluation of bulk density of produced pellets was realized by ten repetitions of measurement and the resulting value represents their arithmetic mean.According to ISO 17828, the measured and evaluated average value of bulk density of digestate pellets is 678.08 $kg.m^{-3}$.

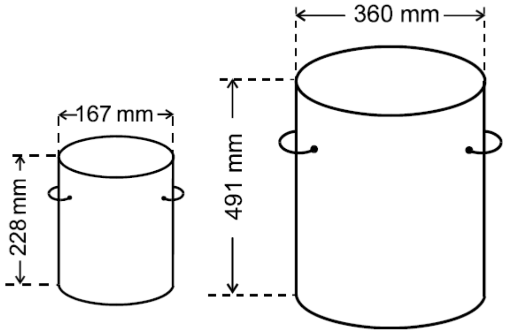


Fig. 9Standardized measuring containers for measuring bulk density

3.2 Mechanical durability

Mechanical durability is another important indicator of the quality of solid biofuels specified by the ISO 17225 standard (minimum required value is 97.5% by weight).The mechanical durability defined by ISO 17831-1 represents the resistance of compacted biofuel (briquettes and pellets) to shocks and / or abrasion due to handling and transport[12].Large amounts of fine particles can lead to fuel clumping in the consumer's storage facilities, thus stopping the supply of fuel to the boiler.Also, excessive amounts of fine particles can block the feed screw.This is the main reason why such high importance is attached to the low proportion of fine particles in biofuel storage.In addition, increasing the amount of fines in the combustion process also increases the proportion of particulate matter in the emissions, which should be avoided from an environmental point of view.The high amount of fine particles affects the bulk density and increases losses during transport and also increases dust emissions during fuel handling.It should be emphasized that dust can cause explosions during storage or handling.Mechanical durability of each sample of pellets was determined according to ISO 17831-1. Measurements were performed on the device Tumbler tester 1000, where the samples of tested pellets were subjected to a controlled impacts of the mutual precipitations of the pellets and precipitation of the pellets with the wall in the defined test chamber during a defined time period 10 minutes. The mechanical durability of the pellets was calculated from the weight of the sample before insertion into the test chamber and the weight of the sample after the impacts (the fines were separated).

Measurement and evaluation of mechanical durability of produced pellets was realized by ten repetitions of measurement and the resulting value represents their arithmetic mean. According to ISO 17831-1, the measured and evaluated average value of mechanical durability of digestate pellets is up to 99.44%.

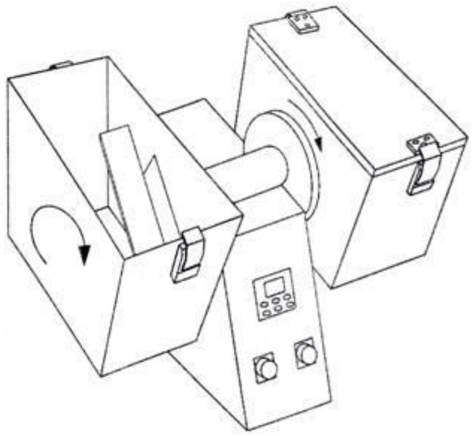


Fig. 10Schematic of apparatus for determining the mechanical durability of pellets according toISO 17831-1

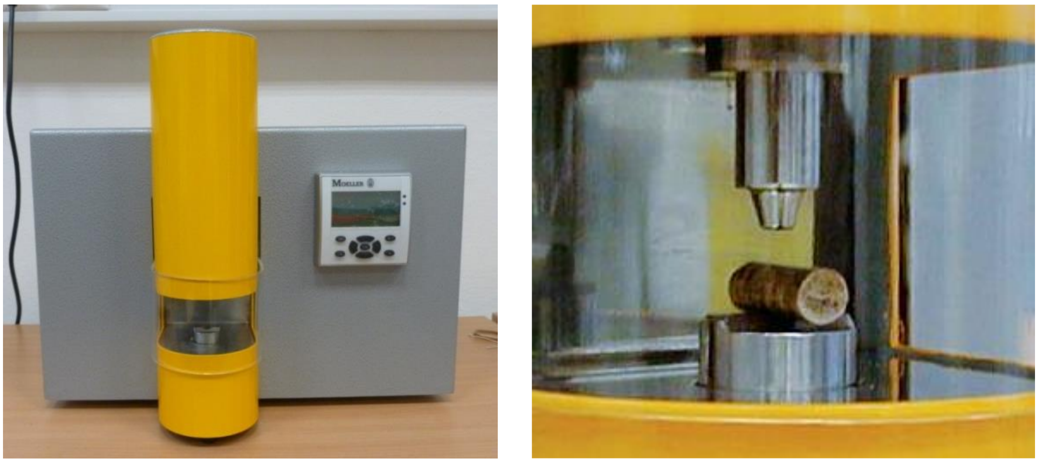
3.3 Hardness of pellets

Hardness of pellets is not biofuel qualitative parameter limited by ISO 17 225. Its importance is very similar to mechanical durability. Pellet hardness is usually related to the quality of densification.The hardness of the pellets actually represents the compressive strength of the pellet.

The determination of pellet hardness is based on comparative method, when the tested sample of pellet is placed between two spikes of

Hardness Tester Amandus KAHL (obr. 11) and the maximum value of the resistance (hardness) of the pellet to the pressure is measured. Values for the hardness are expressed in Newtons.

The average value of pellet hardness was calculated of 20 measurements.The measured and evaluated hardness value of the digestate pellets is 451.85 N.



Obr. 11 Použité zariadenie na testovanie tvrdosti peliet od firmy KAHL

IV. CONCLUSION

Digestate pelleting tests with treated particle size distribution and moisture content have shown that pelleting technology is indeed suitable and progressive for densification digestate into solid biofuel without the need to add any additives.The physical-mechanical quality indicators of the produced pellets (Fig. 12) reach a high level with a stable suitably set pelleting process (pressure, humidity, fraction size, temperature, etc.).

The measured and evaluated operating parameters of the stable optimal pelleting regime (when the highest physical-mechanical quality indicators were achieved) of the digestate are as follows:

- hourly output of the pelleting machine: 92.4 kg/hod.,
- electric current: 30 A,
- compacting pressure: 5.2 MPa,
- optimal moisture content of the raw material at the entrance to the pressing chamber: 19.74 %.

Fig. 12Digestate pellets produced at optimal pelleting technology settings

Acknowledgments

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