HUF 950/$ 4

HUNGARIAN AGRICULTURAL RESEARCH

Autumn 2022

Environmental management, land use, biodiversity

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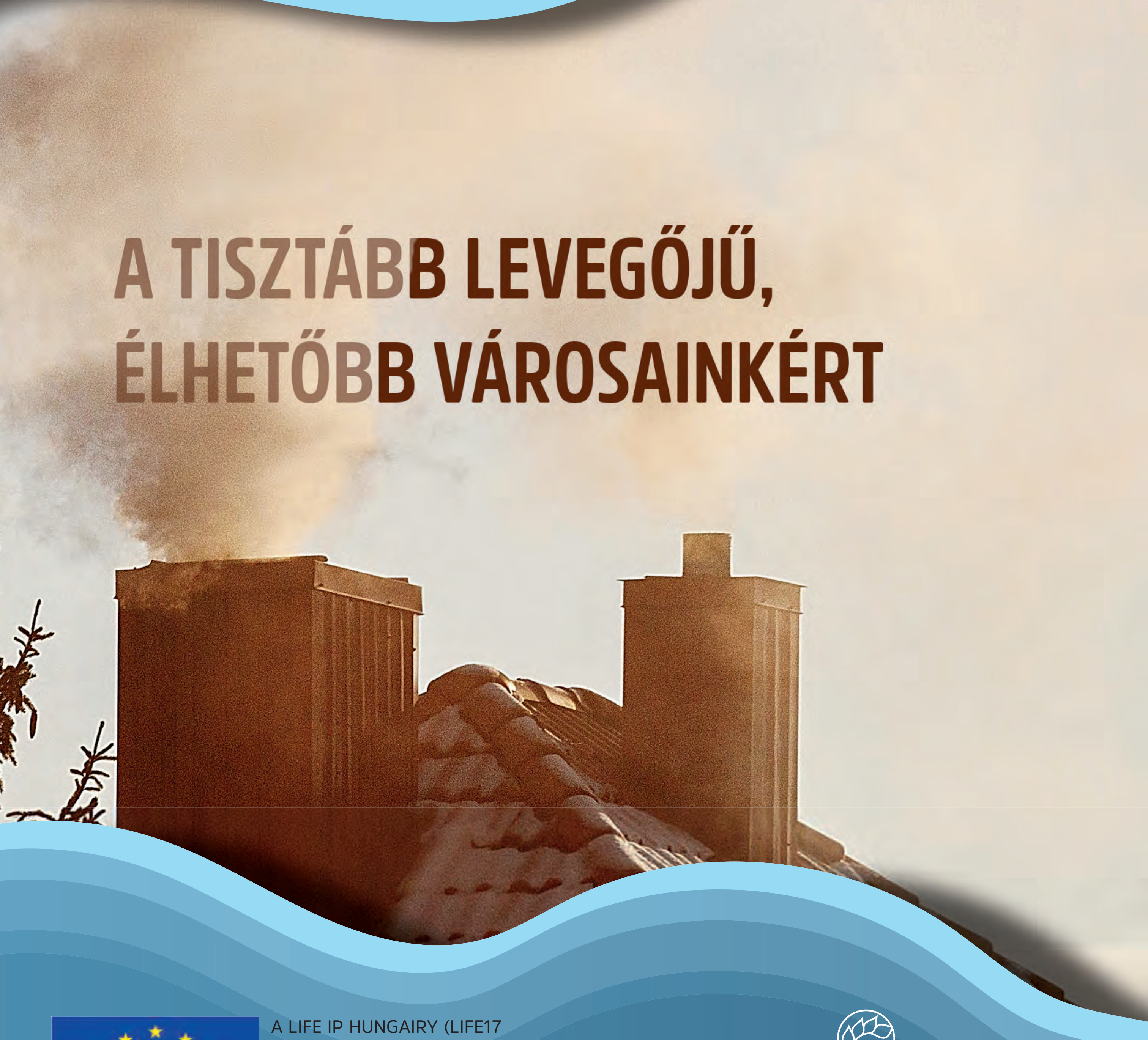

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HUNGARIAN AGRICULTURAL RESEARCH

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Autumn 2022 – Vol.32, No. 3.

Editor-in-chief:
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Cover photo:
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Back cover:
Nóra Koplányi

Published by

HERMAN OTTÓ INSTITUTE NONPROFIT LTD.

H-1223 Budapest, Park u. 2. Hungary
www.agrarlapok.hu/hungarian-agricultural-research I info@agrarlapok.hu
Publisher: Péter Bozzay
Owner

MINISTRY OF AGRICULTURE

Editorial Office
Herman Ottó Institute Nonprofit Ltd.
H-1223 Budapest, Park u. 2. Hungary

Subscription request should be placed with the Publisher (see above)
Subscription is HUF 3900 (only in Hungary) or $16 early plus $5 (p & p) outside Hungary
HU ISSN 1216-4526

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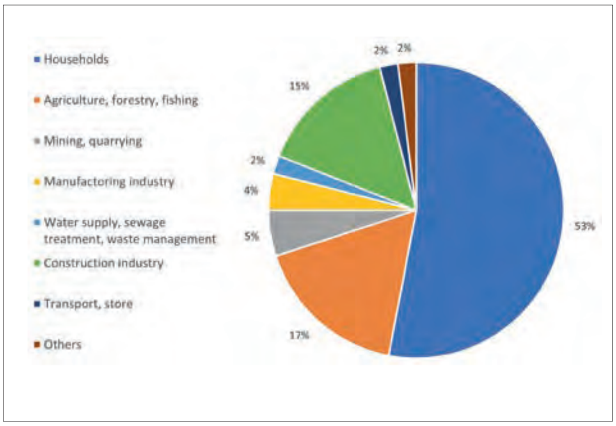

BIOGAS POTENTIAL AND CALORIFIC VALUE OF DIFFERENT AGRICULTURAL MAIN AND BY-PRODUCT

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ABSTRACT

This study assessed the biogas potential and calorific values of the different agricultural main and by-product. Adequate management of different agricultural biomass, residues and by-products can reduce their negative impacts on the environment. An alternative way to use for agricultural wastes, biomass to produce biogas or agripellets to heating. Our work is depending on an ongoing project where the aim is to increase the biogas production, increase the capacity of the biogas plant and reassemble the mixture if it is needed. We investigated the methane potential of 14 sample with the Automatic Methane Potential Test System (AMPTS II) (NaWaRo Ltd) and 9 sample calorific values with Elementar CHNS. system. The significance of our research is that due to the measurements we can exactly determine the possible methane production from the local agricultural wastes, biomass. Our results have shown that the retention time is currently is too long, and the feeding frequency of the digester is also too wide. The calorific values of the samples are parallel with the literature. The pelletized product calorific value similar like the dry wood or straw.

Keywords: biogas potential, calorific value, agricultural residues

INTRODUCTION

The use of biomass, including biogas, for energy purposes is possible mainly in counties with favourable conditions for agricultural production. The technology can be used to reduce fallow land, provide an alternative source of income for local agri-businesses and recover waste from livestock farms and food processing plants. It is necessary to determine the theoretical potential of the county in order to have a comprehensive picture of the amount of biogas that can be extracted in the area. The theoretical potential is the total amount of energy that can be physically extracted. It is important to note that there can be large variations in the specific biogas yield depending on certain factors (feedstock composition, technology used, etc.). The biogas potential of landfills and wastewater treatment plants and the biogas potential of waste materials from the food industry have not been taken into account in our calculations.

Large-scale livestock farming with livestock housing is best suited to the requirements of biogas production. The production of cattle, pigs, sheep, chickens and turkeys produces concentrated manure and causes environmental problems. To calculate the potential, the livestock population of the county was aggregated using the 2021 KSH data, and then the population of the different livestock species per livestock was determined from the KSH data series based on the following:

Based on literature data, the gross average gas yields for each species were calculated. Animal species produce manure with different properties, so the gas yield can be further differentiated by species In Hungary and Western Europe, "wet process" biogas plants based on slurry containing 5-15% dry matter are the most common.

Calculations show that more than 100 million m^3 of biogas can be recovered from livestock production, with an energy content of 2.21 PJ/year. The calculations do not include the biogas potential from manure from other poultry and other animal species.

The main and by-products from the crop production sector can also be considered as a source of biogas. There are changes in agricultural production in Europe today, where industrial and energy (non-food) crops are increasingly being produced, with food production being reduced.

This process foresees the emergence of a new industrial-energy crop production sector, requiring new agrotechnical, mechanisation and logistical applications. The crops most suitable for biogas production must meet a number of conditions. The characteristics of plants that can be easily integrated into the process must include excellent cultivability, storability, smooth harvesting, high dry matter yield, resistance to pests and, last but not least, excellent digestibility.

MATERIAL AND METHODS

Locally available biogas plant input materials

Organic matter load is an important consideration in sizing, which determines how much organic matter (on a dry matter basis) can be loaded per unit time for a given volume.

The aim of the methane potential test is to investigate the digestibility of the samples under mesophilic conditions (39°C) and the amount of biogas potential that can be produced from the samples.

Determine the formulation leading to the maximum methane yield

FOS/TAC analyses provide guidance on the optimal conditions for methane formation. The FOS/TAC analysis was developed to determine the ratio of acid concentration to buffer capacity in the digestion mixture. FOS is an abbreviation for volatile organic acids, measured in mg acetic acid equivalent/ dm^3, while TAC is an abbreviation for total inorganic carbon (the basic buffer capacity), measured in mg $CaCO_3$ /dm^3. Methane production slows down below pH 6.0 and stops above pH 8.0. The pH can vary greatly if the system is not adequately buffered.

Table 1: Test material characteristics

Sample name	Dry matter content [m/m %]	Organic dry matter content [m/m %]
Liquid separat	5.49	65.40
I. digester	8.51	74.75
II. digester	5.91	70.79
Pre-tank	0.89	63.86
Solid separat	21.05	84.98
Manure	16.04	82.14
Grass haylage	36.86	91.49
Straw	81.42	92.28
Compost	50.71	76.38
Corn refuse grain	83.94	96.79
EKO Nyíregyháza	14.59	97.03
Sunflower refuse grain	82.21	85.88
Corn husk	44.66	93.87
Corn silo	25.1	96.37

In practice, a FOS/TAC ratio of between 0.3 and 0.4 is normal, but each plant has its own optimum ratio, which can be determined by long-term monitoring and system control, whereas a wider optimum (0.15 - 0.45) has been established.

The pH in the digestors of the plant varied between 7.1 and 8.0, indicating that the buffer capacity of the system is about adequate, with only a few cases of significant pH fluctuations.

The basis for pelletisation of potentially available local agricultural by-products

CHNS elemental analysers, used for the calorific value determination of various agricultural products, offer the possibility of rapid determination of carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) in organic matrices and other types of materials.

The calorific value is the amount of heat that is released when a unit mass of fuel is burnt perfectly, if the temperature of the fuel before combustion and the temperature of the combustion products after combustion are both 20°C, the carbon content of the fuel is present in the combustion products in the form of carbon dioxide, and the initial moisture content of the fuel and the water produced during combustion is in the form of vapour after combustion, i.e. it does not give off any heat of vaporisation when the combustion products are cooled. The calorific value is therefore less than or equal to the heat of combustion.

The advantage of burning agricultural biomass, pelleting, briquetting is that the calorific value is similar to domestic brown coal (15 500 – 17 200 kJ/kg), but cleaner. It has a lower ash and sulphur content than coal.

RESULTS

Locally available biogas plant input materials

In Figure 1, methane production is plotted as a function of time. The length of the digestion time was 30 days, which is considered as an average time. Since there was no significant increase in the overall gas production curve from day 25, it is likely that a longer experiment would not have yielded better results.

The Corn Silo (4 993 Nml) and EKO Nyíregyháza (4 882 Nml) samples gave the highest total biomethane yields.

Lower gas production was recorded in five samples compared to the control sample: Compost, Solid Separat, Liquid Separat, I. Digester, II. Digester.

Figure 1 shows the specific biological methane production in terms of dry organic matter content of the samples (Nml/g oTS) without the amount of gas produced by the inoculum.

Of the test materials, the EKO Nyíregyháza and the Corn Silo samples had the highest specific methane production capacity. By the 15th day of the digestion process,

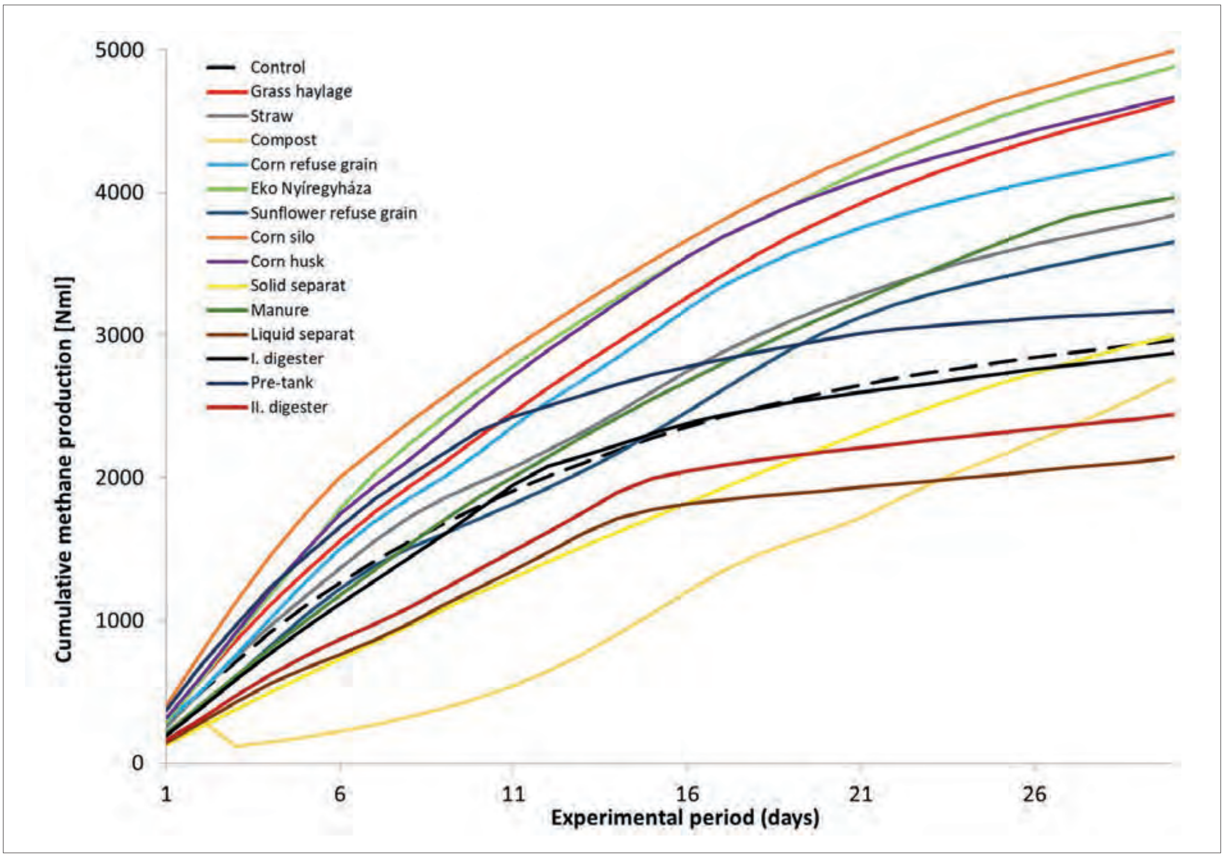

Figure 1: Total methane gas production over the period

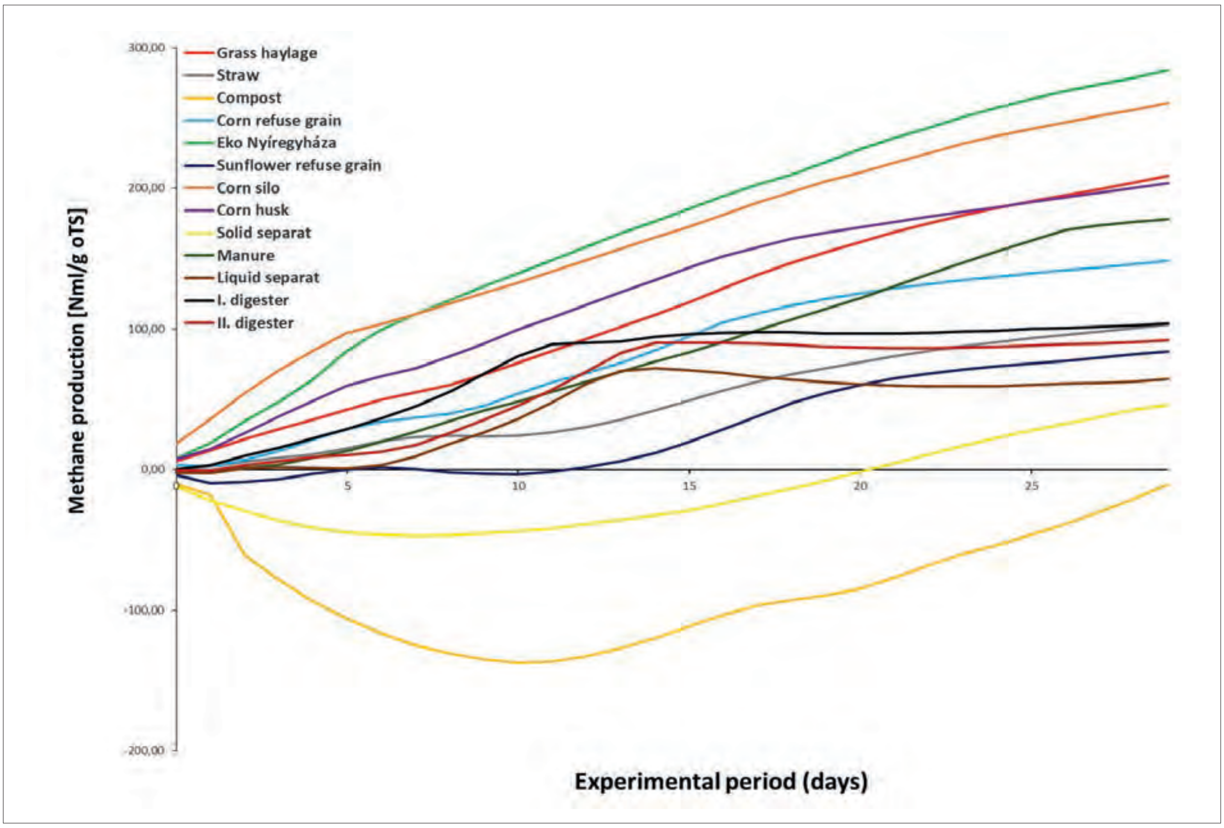

Figure 2: Specific methane production per organic matter corrected for negative control (inoculum)

the specific biomethane production potential of the EKO Nyíregyháza sample was 176.56 [Nml/g oTS], while the Corn Silo sample had a specific biomethane production potential of 165.21 [Nml/g oTS]. After further incubation, their values measured on day 30 of the study increased to 284.06 [Nml/g oTS] and 260.79 [Nml/g oTS], respectively.
Straw, Sunflower refuse grain, Manure, Liqiud Separate and Digester II samples showed reduced gas production at the beginning of the measurement compared to the control, which can be attributed to the characteristics and composition of these feedstocks. After the initial phase, their gas production was in line with expectations.

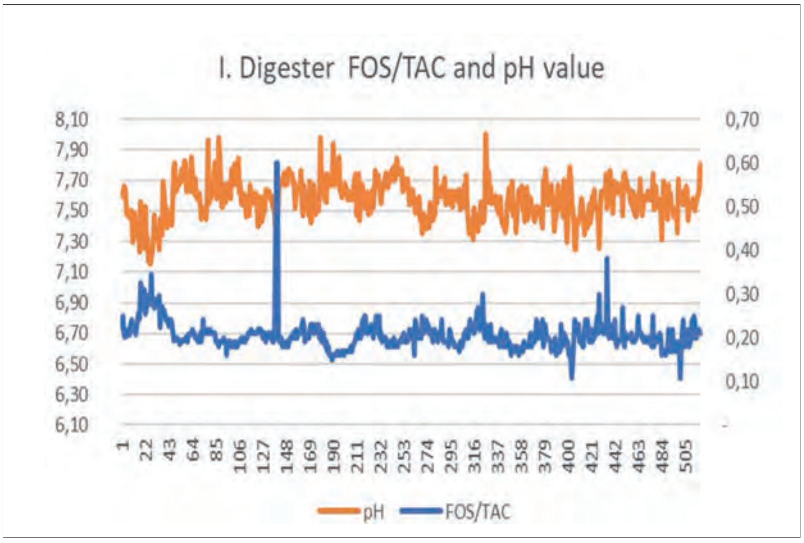

Figure 3: Evolution of the FOS/TAC and pH ratio in digester I

Determine the formulation leading to the maximum methane yield

The data in the diagram 3 and 4 show that the plant is on average characterised by a slightly alkaline chemistry and low FOS/TAC (Figure 3, 4). Overall, although the values obtained are lower than those reported in the literature, this does not mean that the plant is out of balance. However, based on this and on the biogas potential measurements, it is worth reconsidering the frequency of feeding and the hydraulic retention time (HRT).
According to the data of the consortium leader Zrt., in 2021 the number of animals was 2,612, and the total amount of manure produced in livestock farming was 3,962,560 kg, including solid and slurry manure.

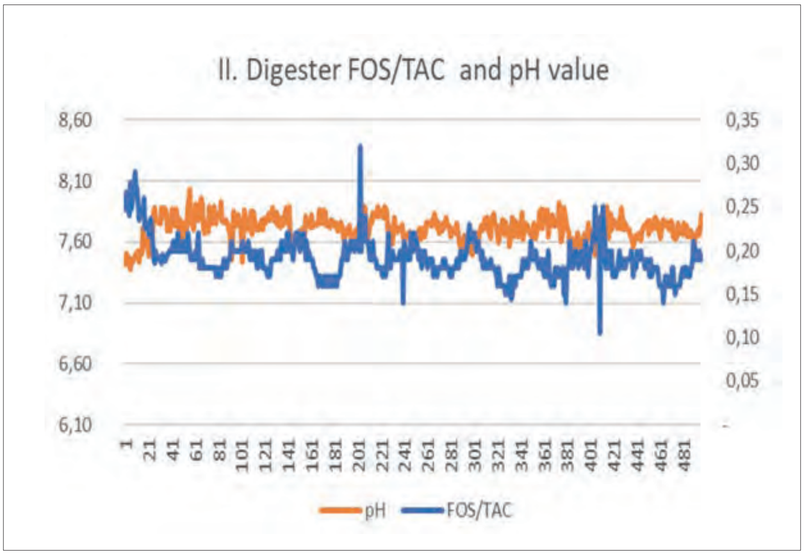

Figure 4: Evolution of FOS/TAC and pH ratio in digester II

For the calculations, only the amount of material that could potentially be taken into account was taken into account, which in 2021 was 2000 t of Corn silo, 2.3 t of Corn straw, 2893.32 t of Corn husk and 83.5 t of sunflower straw.

Table 2: FOS/TAC ratio assessment based on literature data (Mézes et.al.; 2011)
Evaluation of FOS/TAC ratios according to empirical experience

FOS/TAC ratios	Background	Suggestion/Counter Action
>0,6	Highly excessive biomass input	Stop adding biomass
0,5-0,6	Excessive biomass input	Add less biomass
0,4-0,5	Plant is overflowing	Monitor the plant more closely
0,3-0,4	**Biogas production at the maximum**	**Keep biomass input constant**
0,2-0,3	Biomass input is too low	Slowly increase the biomass input
<0,2	Biomass input is far too low	Rapidly increase the biomass input

Calorific value calculation results

The samples with high nitrogen content were solid separation, manure, compost and sunflower straw. Higher sulphur content was also measured in these samples, which may cause corrosion of the combustion equipment in the long term.
As in the literature, calorific values between 16 and 18 MJ/kg were measured, except in two cases, compost and manure.
The moisture content of the samples fell within their typical range, and in order to pelletize or briquette them, pre-treatment is required to achieve the right

Table 3: C/N ratio of samples on dry weight

Sample name	C%	N%	C/N ratio	S%
Liquid separate	45.54	2.14	21.28	0.42
Manure	43.36	1.75	24.78	0.34
Grass haylage	46.51	1.14	40.80	<0.13
Straw	46.06	0.70	65.80	<0.13
Compost	40.64	4.02	10.11	0.71
Corn refuse grain	47.22	1.41	33.49	<0.13
Sunflower refuse grain	47.26	2.49	18.98	0.20
Corn husk	47.13	1.36	34.65	<0.13
Corn silo	39.96	0.80	46.20	<0.13

Table 4: Calorific value of samples on a dry matter

Sample name	Calorificvalue MJ/kg
Liquid separate	16.830
Manure	15.784
Grass haylage	16.792
Straw	16.769
Compost	14.161
Corn refuse grain	17.333
Sunflower refuse grain	17.961
Corn husk	17.218
Corn silo	18.200

Table 5: Moisture and ash content of samples

Sample name	Moisture content % moisture	Ash content %
Liquid separate	21.05	15.26
Manure	16.04	18.47
Grass haylage	36.86	8.62
Straw	10.55	8.36
Compost	50.71	25.50
Corn refuse grain	83.94	3.30
Sunflower refuse grain	82.21	14.27
Corn husk	44.66	6.32
Corn silo	25.10	3.68

moisture content. The ash content was well below the ash content of lignite. Compost and manure only showed higher values. Based on the results of the sample analysis, the most suitable feedstocks for pelleting can be clearly selected from the locally available biomass raw materials.

CONCLUSIONS

These researches were completed within a project whose aim was to take a good practice for the implantation of an innovative biomass based renewable energy production and use. At least the final output of the system will be renewable energy and energy carriers, which are and will continue to be of key importance from both an environmental and energy security perspective.

ACKNOWLEDGEMENTS

The authors would like to extend their thanks to VP3-16.1.1.1-4.1.5-4.2.1-4.2.2-8.1.1.1-8.2.1-8.3.1-8.5.1-8.5.2-8.6.1-17 "Creation of Innovation Operational Groups and Investment for the implementation of innovative projects", call number 1907643541, and the participant for the support. The research was also supported from the NRDI fund (National Laboratories Programme) by the National Research, Development and Innovation Office (NRDI) and the Ministry of Culture and Innovation (KIM) within the framework of the Agrotechnology National Laboratory project.

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