Application of pre-treatment for enhancing biogas production from plant-based agricultural waste

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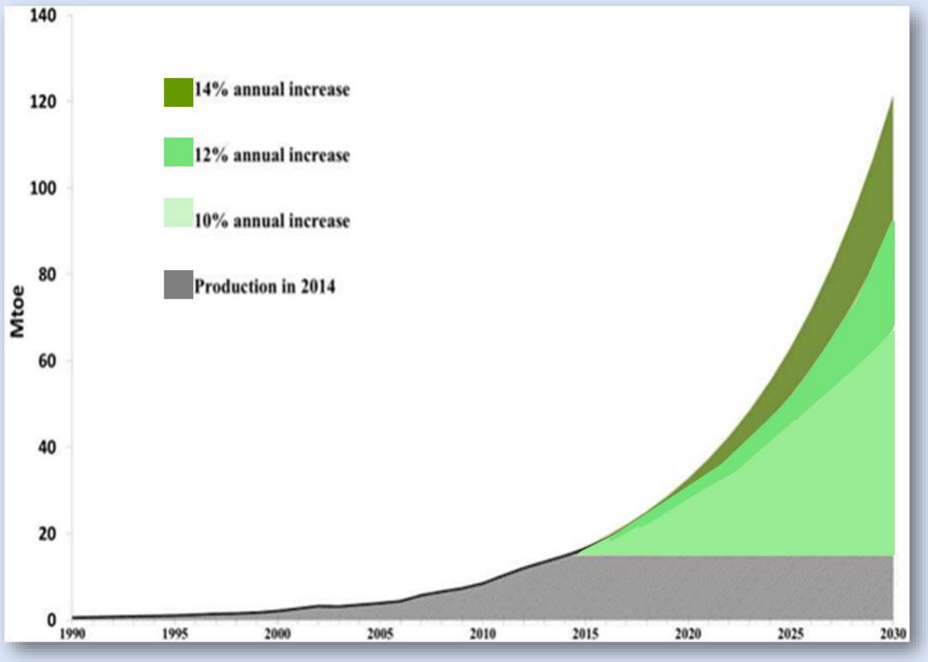
INTRODUCTION

The need for renewable energy has been increasing in recent decades. Among them, energy derived from biomass and biogas is becoming dominant. One of prediction is that in the next 15 years the needs for energy will increase by 50 %, as it was published in [1].



Prediction of biogas production in Europe

Agricultural waste are defined as the residues from farms, poultry houses and slaughter houses, harvest waste, fertilizer run off from fields, salt and dried sludge from fields.

Biogas is produced by the microbiological process in anaerobic conditions (without the presence of oxygen). Anaerobic digestion (AD) is the process whereat anaerobic bacteria break down organic matter, and as products obtained are heat, the rest of fermentation and biogas [2]. This process depends on several factors such as: the pH of the fermentable medium, the ratio of carbon to nitrogen in the fermentable substrate, the retention time, working pressure, temperature and the content of organic matter in the digester [3]

Pre-treatment methods

The pre-treatment is a method which breaks down the link between lignin, cellulose and hemicellulose, improving biodegradability and destroying cell walls in agricultural straw, in order to increase the enzymatic and sugar accessibility, which are used in biogas production, see [4]. Pre-treatments can be classified into four categories**:** physical methods, chemical methods, biological methods and combination of these methods.

The aim of pre-treatment technologies is:

- Make AD faster,
- Increase of biogas yields,
- Usage of new and locally available substrates (for details see [5]).

The application of pre-treatment could reduce the costs of raw material, make the production faster and make the biogas production more economical. Moreover, the application of pre-treatment increases the utilization of substrate, here residues of agricultural plants.

MATERIALS AND METHODS

Manure is used as a basic substrate in all experiments. The dry matter in manure is usually in the range 3-8% [18], therefore manure is suitable for mixing with other substrates which have a higher percentage of dry matter. The selection of the main substrate is made of two agriculture plant residues with high content of cellulose, lignocelluloses and hemicellulose: wheat straw and corn stover (all residues of corn). The selection is also made with regard to available materials in the environment. The retention time of materials with this content is 30 to 40 days in mesophilic conditions regardless whether treatment or pre-treatment has been done.

COMPOSITION OF WHEAT STRAW

Component	%
Hemicellulose	21- 26
Lignin	11-23
Cellulose	33.5 -40
Insoluble ash	7- 10

COMPOSITION OF CORN STOVER

Component	%
Hemicellulose	≈30
Lignin	18- 20.7
Cellulose	37.4-38.1
Insoluble ash	5.2-8.8

Based on the composition of wheat straw, ODM (Organic Dry Matter) is approximately 84%. The amount of dry matter is per day and the total amount of material, according to the useful digester volume of 300 liters (0.3m^3), is approximately 0.7 kg of dry matter per day.

Pre-treatment process

The pre-treatment is performed as a combination of mechanical and alkaline treatment. Material granulation - mechanical treatment, achieves almost uniform size (1 cm) for treated plants. The solution for the alkaline pre-treatment process is 6% NaOH. Treatment time is 30 days and the mixing period in the pre-treatment is 10 minutes, on a daily basis. The volume of the pre-treatment reactor is 100 liters.

The device designed for chemical pre-treatment

Anaerobic Digestion

The capacity of the reactor is 400 liters. The volume of useful space for anaerobic digestion is 300 liters. Required temperature in the reactor is in the range 35 - 37 ^{0}C, as it is designed for mesophilic digestion. The reactor is a jacketed vessel, so designed temperature is provided in the jacket by circulating water. During the process, the temperature is maintained in the range of ± 1 ^{0}C, because methanogenic bacteria are sensitive to temperature change. The water temperature in the jacketed vessel is provided through a solar collector with a defined surface, see [6], so it could be said that it is a hybrid system – we designated it: ASB – anaerobic solar bioreactor. More about the thermic part of the system and necessary computations are given in [7]. The agitation in the reactor is 2 times per day, and C/N ratio during the process is in the range 20-25.

PRE-TREATMENT AND ANAEROBIC DIGESTION DURING EXPERIMENTS

Materials	Chemical pre-treatment	Granulation	Retention time (day)	Manure	Period of pre-treatment
Wheat straw	no	≤ 1 cm	30	yes	0
Wheat straw	yes	≤ 1 cm	30	yes	30
Corn stover	no	≤ 1 cm	30	yes	0
Corn stover	yes	≤ 1 cm	30	yes	30

RESULTS

The obtained results show an increase in biogas yield for the treated substrate compared to untreated. The obtained results show that biogas yield from wheat straw is increased by 15% after a combination of mechanical and chemical pre-treatment, while biogas yield from corn is increased by 28% in the same pre-treatment conditions.

The device parameters are:

- The motor, power 1KS 1400 rpm (mixer)
- The pump could achieve 1700 l/h (for alkaline solution dosing),
- The motor pump and the pulley system is in transmission 1:1
- The reactor capacity 100 l,
- The hopper volume 0.5 m^3

BIOGAS YIELD BEFORE AND AFTER MECHANICAL AND CHEMICAL PRE-TREATMENT

Materials	Pre-treatment	Retention time (day)	Substrate temperature (^{0}C)	Biogas yield (м^3)	Yield increase
Wheat straw	no	30	28	4.25	
Wheat straw	yes	30	29	4.90	**15%**
Corn stover	no	30	28	4.50	
Corn stover	yes	30	32	5.75	**28%**

CONCLUSION

Considering that biogas is often obtained from agricultural waste, this work analyses pre-treatment of plant-based agricultural waste, as a process that is more and more in use prior to anaerobic digestion. The experimental part of the research included the development of a device for chemical pre-treatment of agricultural plant-based waste and its application to the alkaline pre-treatment of previously granulated wheat straw and corn stover. After anaerobic digestion in the pilot plant (also developed by the authors of this paper), the results showed that a combination of the granulation of raw materials and alkaline treatment is effective pre-treatment for increasing biogas yield (15% for wheat straw as a raw material and even 28% for corn stover).

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