CONTRIBUTIONS TO ENERGY RECOVERY FROM BIOMASS FOR BIOGAS PRODUCTION

The research carried out in the PhD thesis brings a contribution to the identification of several new methods and materials for the energy utilization of biomass to biogas. The research aimed to analyze the possibilities of using organic waste in combination with different wastewaters for the production of biogas. A representative number of bibliographic references were studied in the current stream of knowledge in Romania and globally and some valuable elements have been identified in relation to the possibility of harnessing waste in the circular economy.

Scenarios were also made based on which it has been demonstrated that the recovery of organic waste to biogas is a solution for reducing pollution of environmental factors, in particular by reducing greenhouse gas emissions.

The research of the existing legislative framework pointed out the efforts to be made at European, but also global level for sustainable development, reducing the effects of climate change, promoting energy from renewable sources, supporting a circular economy and managing waste. For the implementation of the objectives established by legislation, quantifiable targets have been identified, economic mechanisms have been created and technological research has been encouraged.

A. Study of a representative number of bibliographic references in the current stream of knowledge in Romania and around the world

There have been studied works from Romanian and global literature on the process of anaerobic digestion of organic waste, sludge and animal sewage as a main substrate.

The research studies have shown that, the organic waste is suitable for capitalization by anaerobic digestion and biogas production.

It has also been shown that food waste is a very good raw material for the production of biogas with a high efficiency of biogas production.

Low yields have been obtained through anaerobic digestion of sludge , and it was demonstrated that co-digestion of this with other organic materials increased the production of methane.

Biogas plants where anaerobic digestion of livestock manure occurs as the main substrate can also work by adding organic waste, sludge, wastewater with high organic charges from the food industry, food waste.

The obtained mixture of materials increased the biogas production. It has also been found that pretreatment of materials intensifies the anaerobic digestion process and that by the addition of trace elements, biogas production can be improved for all substrates used.

B. Establishing of a working method, both in a theoretical and experimental way to achieve the goal.

For this purpose, different types of recipes have been tested in order to identify materials with high potential for the production of biogas, qualitative and quantitative. The tests were carried out on the pilot installation used for the experimental part, which is apatented invention , "process and installation for obtaining biogas from biomass" [patent number 122047] and on the small installation in the multifunctional laboratory of the Timisoara Faculty of mechanics.

B. 1. Presentation of the installations where different types of recipes have been tested

B. 1.1. Small Installation

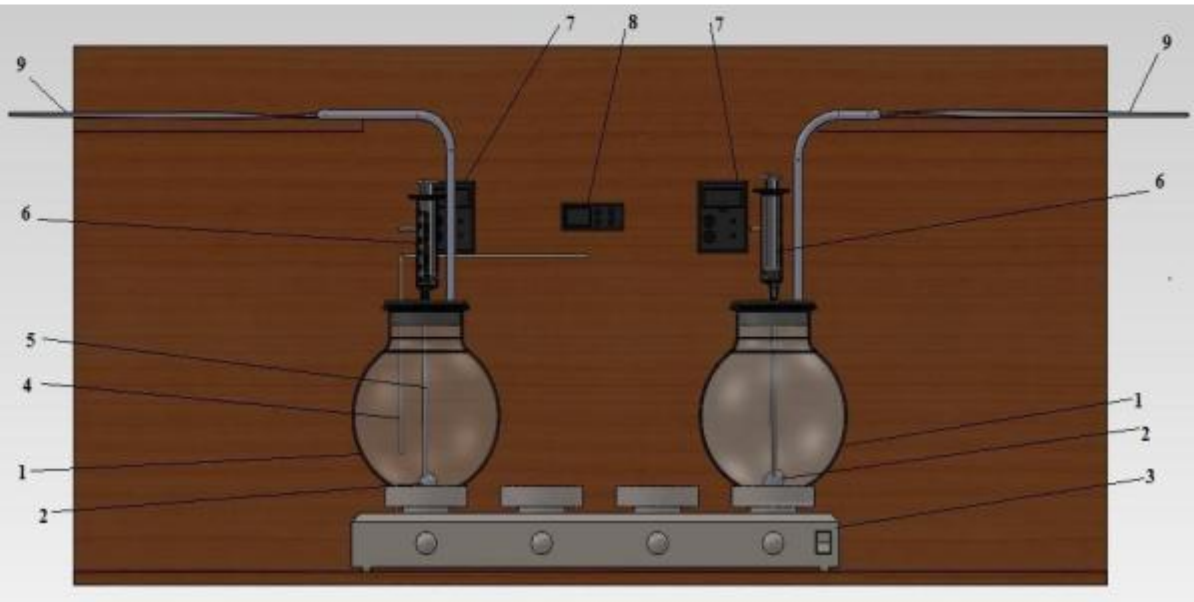


Figure B. 1.1.1. Small-scale installation scheme [Varga and others-a]

The components of this installation are:
1 - glass vessel with a volume of 6l, covered with a coat of paint, for fermentation
2 - magnets positioned in the lower part of the glass vessels, used to agitate the molecules of worn waste materials
3 - device used to heat matter from vessels
4 - thermocouple used to measure the temperature of the fermentation vessels
5 - sampling system and correction of the pH of matter inside the vessels
6 - syringe used for sampling of vessels
7 - pH controllers, connected to the pH sensors inside the vessels
8 - temperature controller, connected with thermocouple inside the vessels, to determine the temperature at a specified interval
9 - gas bags with a volume of 2 l for the collection of biogas from the fermentation process

To prepare this small-scale installation, several stages were followed:

- The fitting of metal caps for glass vessels has been made to introduce all systems and ensure optimum sealing during the process.

- Glass vessels have been dyed to obtain the best fermentation process and all connections have been sealed to reduce gas losses during the process.

- The final ensemble will allow the use of two materials or one combined material and the substrate used for fermentation to compare parameters of the process parameters (pH, quantity of biogas produced).

After performing these small-scale operations, tests have been performed to verify the correct operation of all components. The command part and the pH sensors, the temperature sensors and the electrical part of the installation have been tested.

After double control, the installation is further prepared to produce biogas in small quantities or for experimental purposes.

Figure B. 1.1.2. Sensor verification on the installation [Varga and others-a]

B. 1.2. Testing of different types of recipes in the pilot facility

Determination of the actual potential for biogas production in suitable quantities and with the highest methane content in its composition was carried out in the pilot facility.

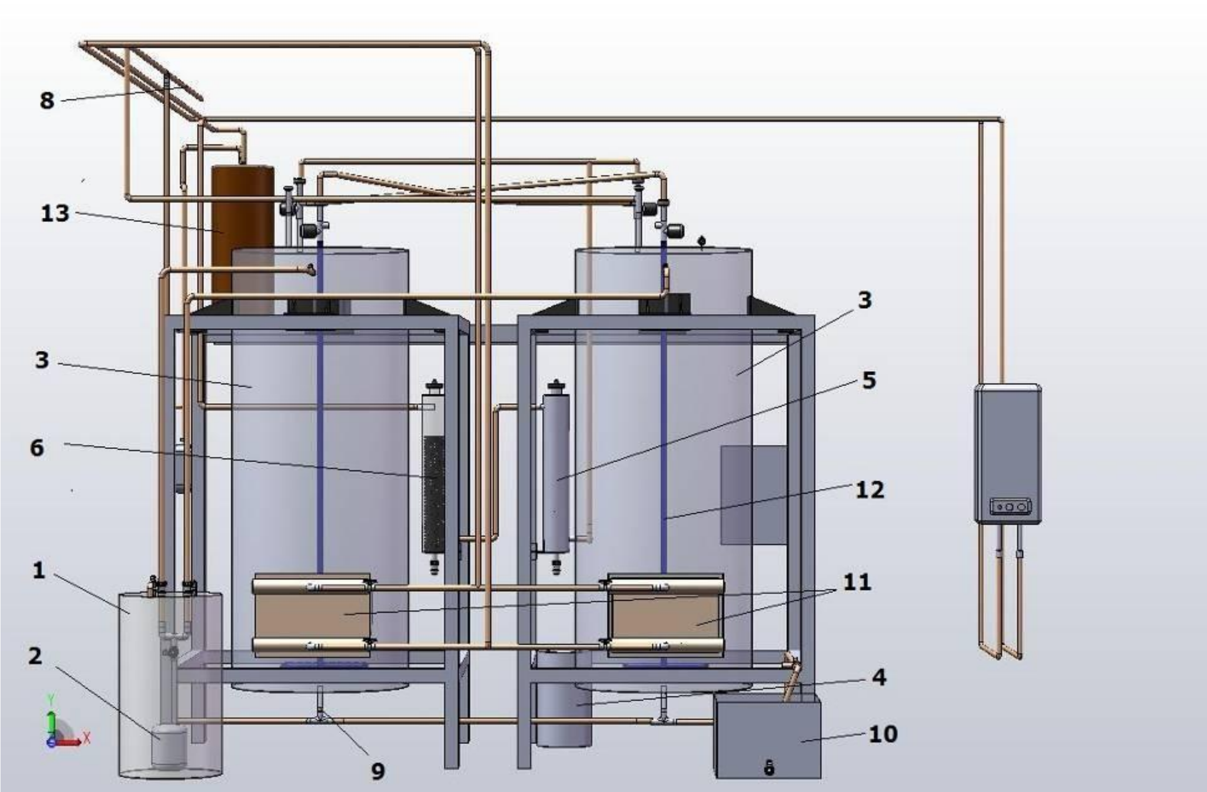


Figure B 1.2.1. Diagram of the principle of the pilot installation [[Patent invention Number 122047], [Cioabla and others]

From the reservoir where biomass is deposited, it passes through a mill, and then it is sent to the reservoir where it is homogenized with water (1). The homogenized matter is transported with the submersible pump (2) and sent to the fermenters (3). This installation shall also be fitted with a tank containing a correction agent (4) that ensures the pH. The biogas result passes through a filter (5) for the retention of H_2S (hydrogen sulfide) and then through a system (6) that partially withholds CO_2 (carbon dioxide), after which it can be compressed into the adjacent system (7) and the resulting biogas is collected through pipelines (8) to be used. The material used is downloaded through a gravimetric system (9), and part of the resulting liquid is separated (solid by the liquid by decanting) through the system (10) and sent to the sewage. The reactors are heated by the heating system (11), and the homogenization is achieved by a bubbling system (12). In order to keep small quantities of biogas for analysis purposes, the plant is also equipped with a smaller-sized supply tank (13).

The main components of the installation are:

- The preliminary biomass preparation system consists of a hydrolysis reactor in stainless steel. In the preparation vessel there is a submersible pump used for waste water to perform homogenization of the material then inserted into the anaerobic fermentation reactors. It should be taken into account that during the preparation of the suspension, it is important to monitor the variation of the pH in the preparation tank, and this can be done using a portable pH measuring device.

-Anaerobic fermentation tanks

They are equipped with a reservoir heating system by means of heat exchangers mounted at the bottom, consisting of 6 coils/heat exchanger and supplied with hot water from a boiler located near the plant.

To avoid heat loss, the connection path between the boiler and the installation is insulated. The tanks are also thermally insulated with insulated aluminum foil to reduce heat losses with the exterior.

B. 2. Gas exhaust system. [Patent invention number 122047]

The biogas resulting from the anaerobic fermentation in the pilot plant is evacuated by a gas exhaust system consisting of a pipe system including four electrovalve fitted by two on each tank and electrically controlled from a control panel when the pressure reaches a certain preset value. The system is also equipped with a reservoir for storing small quantities of biogas for analysis, i.e. a system with gas meters for each reservoir for monitoring the amount of biogas evacuated and the obtained production.

B. 2.1. Biogas Treatment System

It consists of 2 filters, one with the role of retaining traces of hydrogen sulfide (H_2S), and the other with a role to retain CO_2. It is positioned between the two tanks of anaerobic fermentation.

B. 2.2. Carbon dioxide restraint system

It consists of a stainless steel tank, a liquid separator, a buffer vessel from which the exhaust gas is aspirated by an air-cooled Haug model compressor, at a pressure between 1 – 6 bar and then inserted into a cylinder at a pressure between 10 – 26 bar. The stainless steel tank is located on a heating device, the temperature in the system reaching between 50-60°C and the liquid exhausted from the CO_2 filter is taken from a container using a dosing pump of the same type as the one used to wash the biogas.

Figure B. 2.2.1. Overall CO_2 retention system, [patent invention number 122047],

B. 3. Measuring equipment, control and devices

The main equipment used for the control process are the pH, temperature and pressure sensors, as well as the related monitoring elements (dosing pumps, electrical valvves). Gas analyzers are used to measure the characteristics of biogas (CH_4, CO_2, H_2S).

B. 4. Process monitoring equipment

The equipment for monitoring the anaerobic fermentation process in the pilot installation is controlled in the installation Control Panel.

This board has possibilities of automating the process from the point of view of the biogas evacuation at pre-established pressure with the help of the electrical valves positioned on the installation lid, respectively the actuator of the dosing pumps to achieve pH correction. In order to be able to study in detail the fermentation process and to determine the quantities discharged from each tank, the control of the electrical valves was automated. Also, the continuous use of dosing pumps has not been imposed, which is why they were commissioned for research.

B. 5. Measurement of CH_4 and CO_2 concentration [Patent invention number 122047],

To determine the qualities of biogas obtained it is necessary to measure the concentration of these two components – methane and carbon dioxide. This was done with gas – the DELTA 1600 s IV analyzer [user Manual]. The analyzer can measure methane and carbon dioxide in percentages of up to 100% density parts. Optionally, the analyzer can determine the content of CO up to a percentage of 10%, O_2 in percentage up to 25% and NO up to 5000 ppm.

B. 6. Synthesis of the operations necessary to put into service the experimental plant for the production of biogas

B. 6.1. Preparation of the facility for experiments by providing utilities corresponding to the various processes needed to be accomplished [Varga and others]:

- electric power for the control panel and electrically operated elements of the various plant systems;
- the methane for the hot water boiler for the heat exchangers;
- hot water for suspension preparation- solid biofuels;
- CaCO3 to achieve pH correction;
- chemical reagents (acetic acid) for the use of acid hydrolysis;
- chemical calibration substances for calibration of pH sensors;
- measuring and control systems for functional parameters (exhaust gas meter, heating boiler gas meter;
- other thermocouples, thermometers, manometers; valves, electric valves, sensors)

B. 6.2. Starting/Stopping the experimental plant for biogas production [Cioabla and others]

At the start of the installation, the following steps are important:

- the verification of the structural integrity of the plant;

- tightness checking of tanks and exhaust system;
> calibration of pH sensors;
> check all measuring and control equipment;
> reading gas meters for installation and heating boiler;
The preparation of the suspension in the preparation vessel;
> Introduction of the suspension inside the anaerobic fermentation reservoirs using the submersible pump and the supply duct system;
> read the initial pressures in the system after completion of the supply process;
> The execution of 2 – 3 recirculation of suspension for each tank in part in order to ensure a good homogenization of the material inside them;
The realization of the initial pH correction for the charge to start with a pH as close as possible to the neutral one.
During the entire fermentation process the characteristics parameters will be monitored, namely the proper operation of all equipment, the quantities of gas evacuated, will be noted the gas analysis related to the values recorded by the the measurement and control equipment, respectively the experimental determination of the upper and lower calorific power for biogas obtained.
For the purpose of completing the installation, the following steps will be complete:
The entire amount of gas remaining in the system will be emtied;
> Read the final value at the end of the gob of the gas meters for the installation and the hot water supply boiler;
> Washing the dosing pumps>The emptying of the suspension inside the anaerobic fermentation reservoirs;
> Storage of solid waste for drying;
> Removing the pH sensors from the system and placing them in distilled water for preservation during the stationing of the processes in the installation;
>Check the power supply stop of all equipment in the system.

C. Experimental results. Results interpretations

The laboratory determinations consisted of two parts related to the obtaining of biogas: analysis of physical and chemical properties for different materials in order to further use them in processes of anaerobic fermentation and laboratory determinations on a scale of 5 L and within the pilot installation with the drawing of related conclusions related to the potential for use of these residual materials. Wastewater was tested from the brewery and the wastewater treatment plant in Timisoara, in combination with different materials in order to identify the potential for the recovery of wastewater through anaerobic digestion.

C.1. Comparative determination of co-fermentation using residues and wastewater from the brewery for small scale biogas production

An analysis of the physical-chemical properties was made s and the laboratory determinations were made at 5 L scale for wastewater from the brewery in Timisoara, and in combination with the milk whey and molasses from the sugar factory, in order to identify the potential for using these residual materials for anaerobic digestion [Varga et al.-a]

The following materials were experimentally tested only on the laboratory scale:
-Wastewater from a beer factory located in Timisoara,
-Wastewater from a brewery, mixed with 10% parts density milk whey,
-Wastewater from a brewery located in Timisoara, mixed with 10% parts density molasses from sugar beet processing.

Analysis of physical-chemical properties of charge 1 of tested materials

Determinations were made for test materials on ash content (dry base) [%], moisture content [%], mean caloric power (dry base) [J/kg], carbon content [%], sulfur content [%], volatile content (dry base) [%], according to [Standard] standards.

These determinations are relevant to the decision on the use of materials for anaerobic digestion:

- the high ash content is an indicator that the tested materials are not suitable for combustion processes for the purpose of their energy recovery.

- the average caloric power indicates a potential from the energy point of view, to determine whether the anaerobic fermentation processes are suitable for the recovery of these materials.

- The high sulfur content of the chosen materials certifies the mismatch of these substrates for combustion processes

- the value of volatile materials reflects hints on the olfactory character of the mixtures.

- the carbon content indicates the potential to capitalize on the anaerobic digestion of the tested materials.

Identification of the potential for use of residual material from the first charge by anaerobic digestion

The graphical representation of the concentration of CH_4 for the analyzed materials reveals that for the sample containing wastewater from the brewery in combination with milk whey, high value of methane content was obtained(maximum percentage of about 70 %), which indicates potential for capitalization in biodegradation processes.

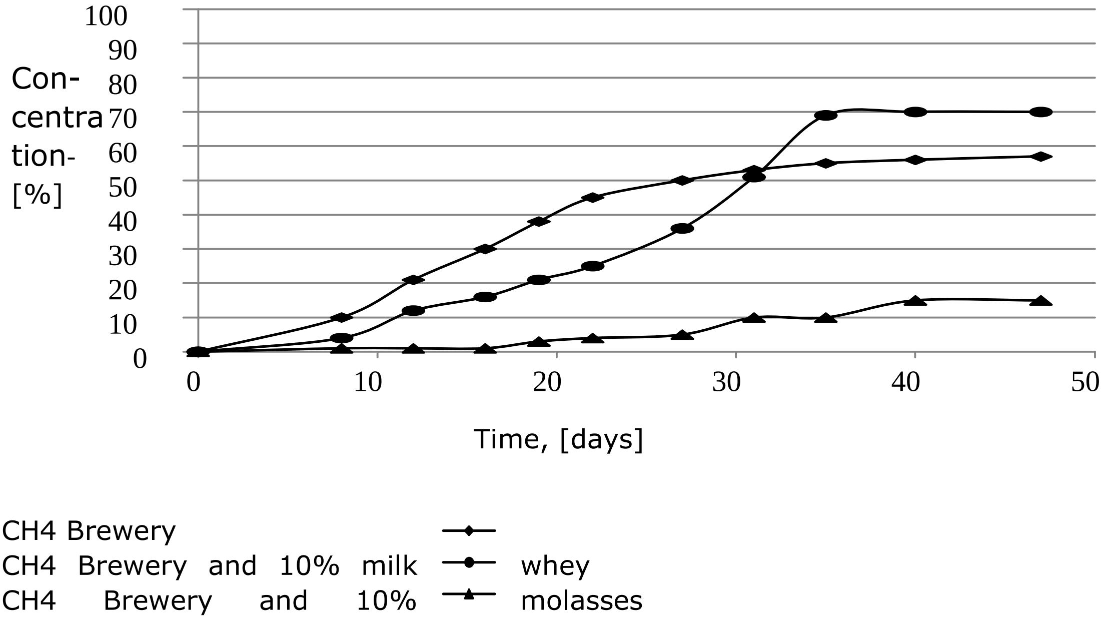


Figure C. 1.1. Graphic representation of the concentration of CH_4 [Varga and others-b]

For the charge containing molasses, the percentage of methane is reduced, less than 20% density parts, this material is not indicated to be used in biodegradation processes. For the charge containing only wastewater from the brewery, it is possible to identify the need for co-fermentation with a view to obtaining higher values in terms of biogas product.

In terms of initial pH values, they were relatively high for two of the three ounces of material. For pH correction, an ammonia-based solution was used (NH_3), 20% concentration in the first days of the process. The charge that contained the mixture with molasses required an extended pH correction regimen. Due to the high sugar content, the first half of the fermentation period was characterized by low pH values, which required an initial stabilization phase much higher than normal, having a negative impact on the biogas production and the methane content this.

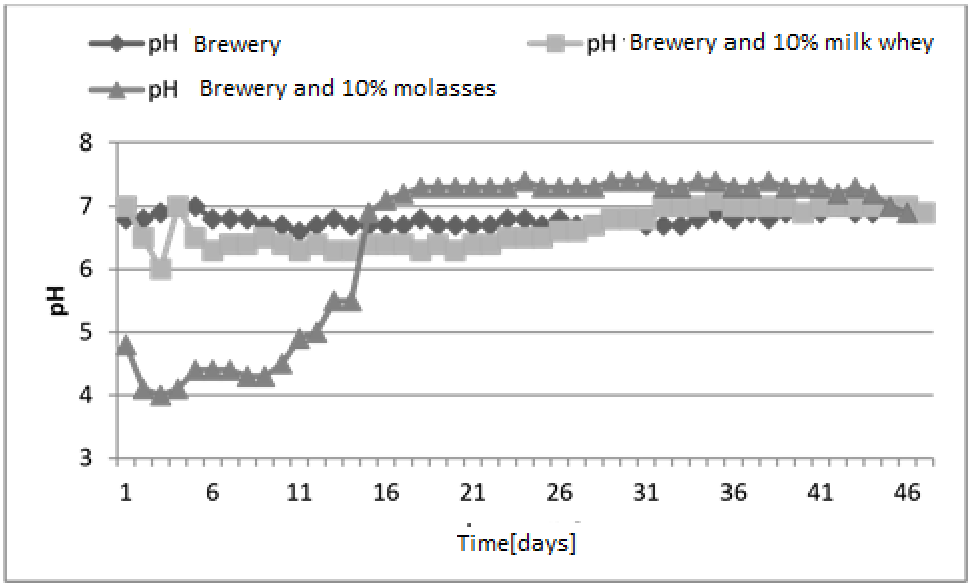
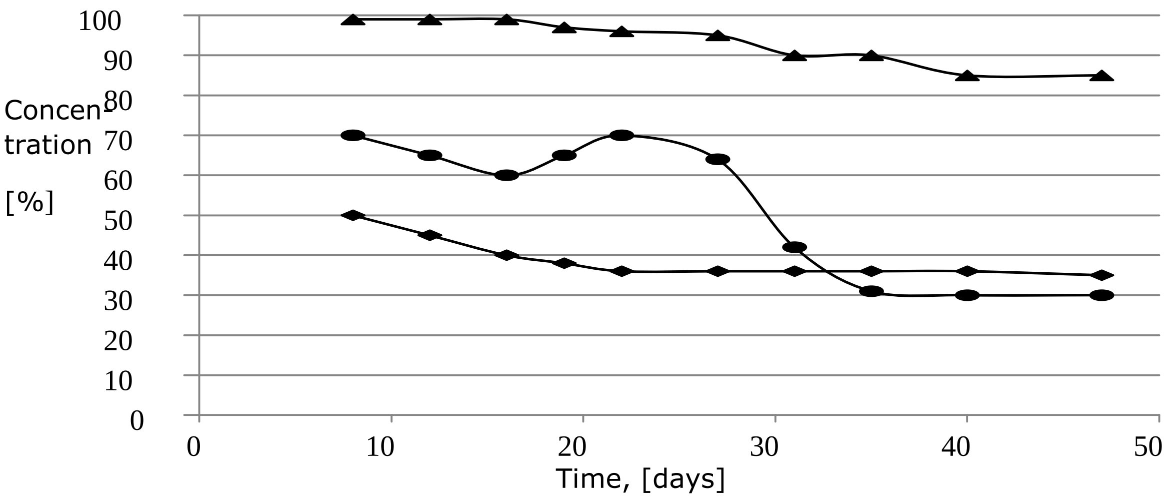


Figure C. 1.2. pH variation [Varga and others-b]

As regards the concentration of CO_2, it is observed that, in proportion to the percentage of methane obtained from the determinations, it may be observed to decrease the carbon dioxide content, proportionately, with the obvious exception of the gob containing molasses.



CO2 Brewery
CO2 Brewery and 10% milk whey
CO2 Brewery and 10% molasses

C. 1.3. Graphic representation of CO_2 concentration [Varga and others-b]

Carbon dioxide levels reach a minimum of about 30% for charge containing milk whey – this involves finding solutions for optimizing the process to bring an even more significant reduction in the existing percentage for this gas.

The material charges produced about 10 L of biogas for wastewater, about 30 L of biogas for mixing with 10% milk whey and only 7 L biogas for mixing with 10% molasses.

C. 2. Comparative determination of co-fermentation using residues and various wastewater for small-scale biogas production

Comparative determinations of substrate co-ferments have been achieved in two reactors containing the following mixtures:

First vessel - wastewater from the water treatment plant, 4% dehydrated sludge from the plant treatment and 5% milk whey;

Second vessel - wastewater from the brewery, 4% dehydrated sludge from the treatment plant and 5%milk whey.

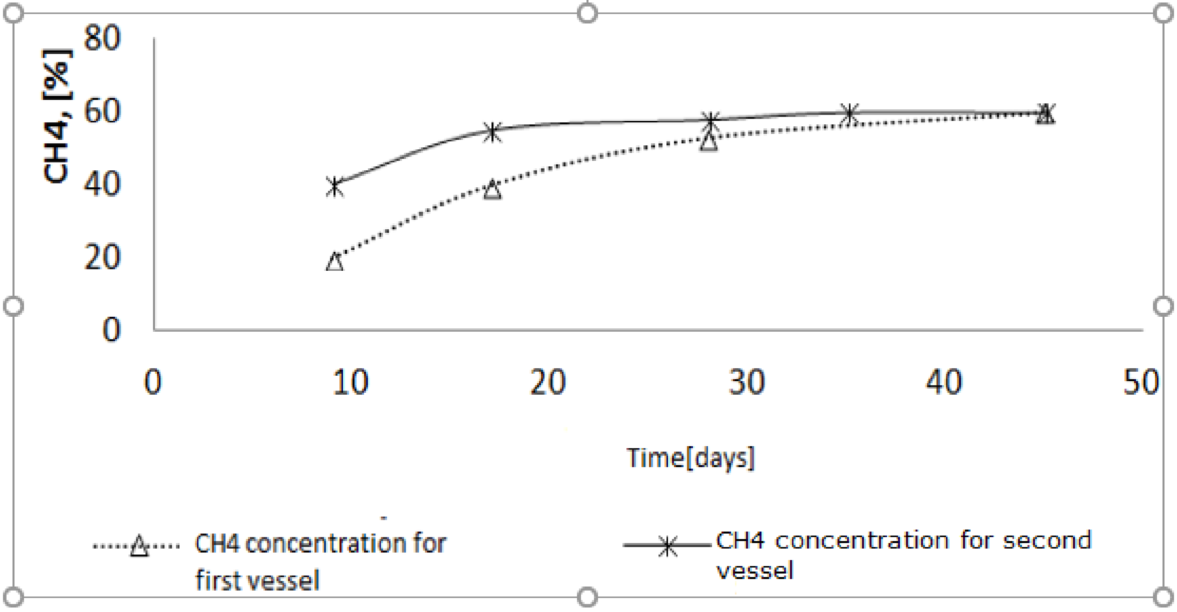


Figure C. 2.1. Graphic representation of the concentration of CH_4 [Varga and others-a]

The gas analyzer used for this task was a DELTA 1600 SIV type, which allows the determination of methane and carbon dioxide to 100% by volume. It is noted that the four values for the first reactor and the five preserved values for the second reactor are corresponding to the average value read during 10 days of trial, and therefore the measurement was divided into four periods of 10 days each. For the second reactor, two measurements were carried out during the last measurement period.

It is observed that the maximum value is about 60% for methane content. This identifies a potential relatively constant combustion process, but for optimum capitalization it is recommended a higher value of the percentage of methane from the composition of the biogas produced.

It should be noted that the values indicated for the reactors correspond to the average values read over 10 days of trial, for this reason there are about four periods of 10 days.

It is also noted that during the charges process the material presents a relatively high value of adjustment, which made the use of the NH solution$_3$ to be done only in the first period of anaerobic fermentation when the pH has not been integrated into the neutral field.

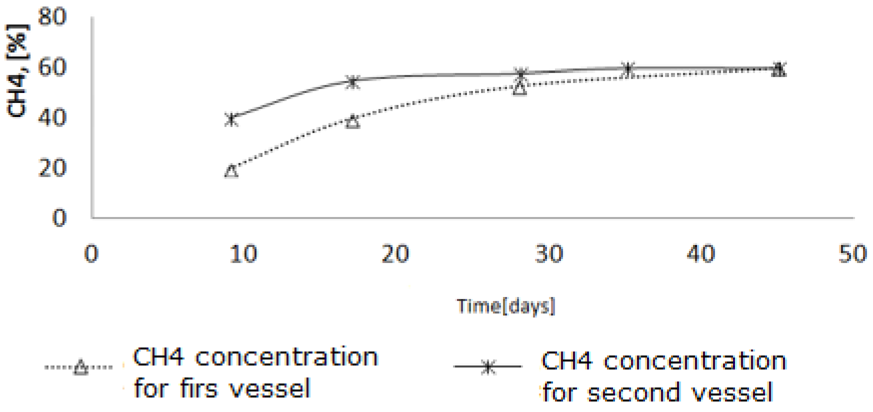


Figure C. 2.2. PH Variation [Varga and others-a]

Variation of carbon dioxide for the two samples:

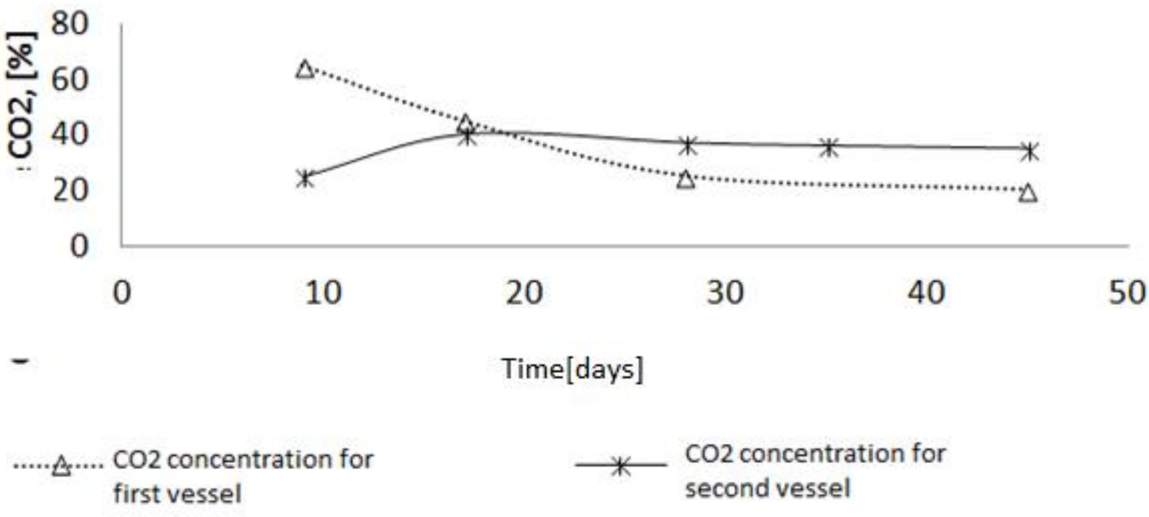


Figure C. 2.3. Graphic representation of the concentration of CH_4 [Varga and others-a]

The quantities of produced CH_4 consisted of approximately 4 liters of gas for mixing with 91% residual water from the sewage plant, 4% dehydrated sludge from the treatment plant and 5% whey of cows and approximately 5 L for the batch composed of 91% residual water from beer factory , 4% dehydrated sludge from plant and 5% milk whey, higher than the one in the first reactor.

The quality and quantity of biogas depends on the organic concentration of the material used, which is a good indication that the residual water in the brewery has a higher concentration in biodegradable material.

C.3. Comparative determination of co-fermentation using waste and wastewater in the pilot plant.

Experimental substrates considered in the anaerobic fermentation processes of the mixture having as a basis wastewater from the wastewater treatment plant and as cereal material degraded maize and degraded barley and having as the basis of wastewater from the material brewery have been tested. Cereal corn degraded and barley degraded**.** This was done for about 45 days, at a mesophilic temperature regime of about 33 – 36°C.

The first tests considered the use of a mixture based on wastewater from the sewage plant and as cereal material degraded maize and degraded barley.

During the tests, the monitoring of pH was considered, the pressures obtained on the installation, respectively the quality and quantity of the biogas produced. The quantity was monitored using gas meters and the partial composition of the obtained biogas was quantified as regards the content of methane and carbon dioxide.

Variation of pH for the materials studied is presented in figure C.3.1.

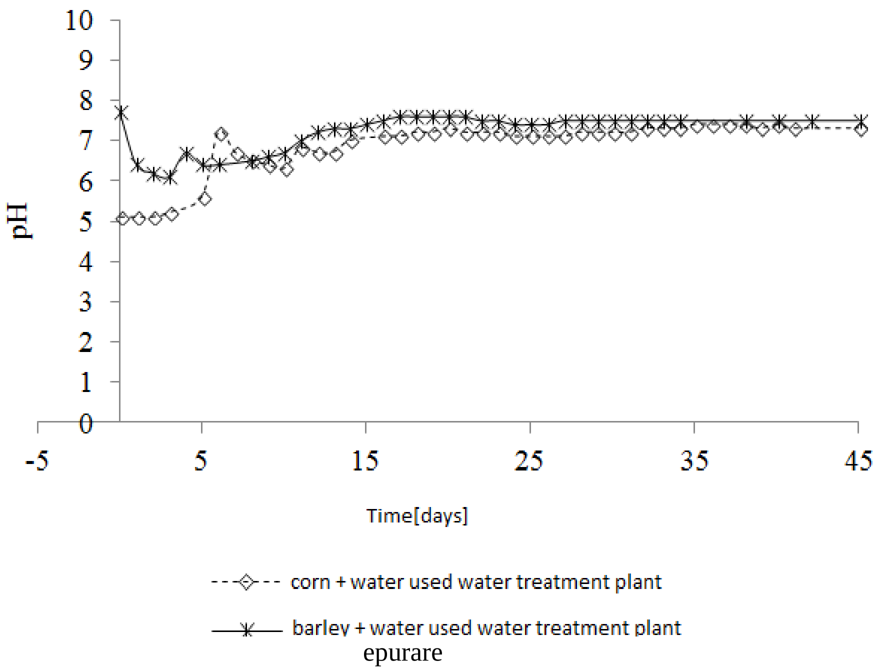


Figure C. 3.1. – pH variation for tested materials

In the figure C.3.1. it can be observed that the initial pH for maize was in the acid field, while for barley, the initial values were relatively atypical in the alkaline field. This can be explained by the fact that an initial correction of pH was made at the loading of the plant, using a caustic soda-based suspension. The initial values were in the field of 5 – 5.2 and 8, respectively, for the two ounces. Thereafter, after about 5-8 days of the process, the pH stabilization was taken on the neutral field, this remains unchanged until the end of the anaerobic fermentation process.

Regarding the variation of the concentration of CH_4, it can be seen that for the two materials studied, the variation of the methane concentration has similar behavior, charge containing degraded maize having a higher speed of increase in the value of biogas methane. At the end of the process, the charge with degraded barley presents a value of about 80% of the volume of methane in biogas, while the charge with degraded maize has a value of about 78% density percent.

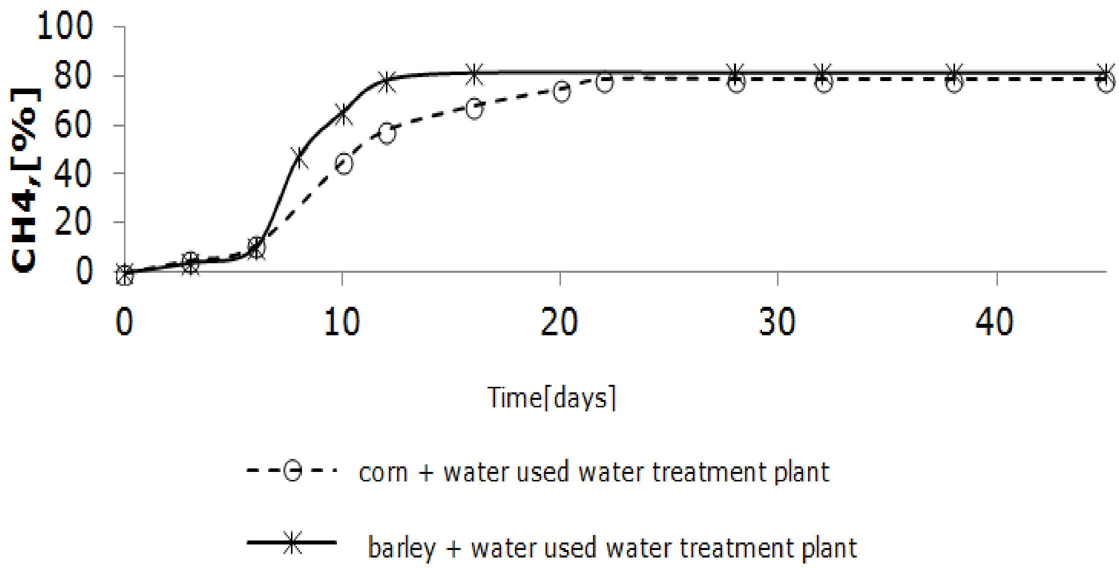


Figure C 3.2 - Variation of CH_4 concentration

Similarly, as the percentage of methane increases, there is a proportional decrease in the percentage of carbon dioxide to values reaching a minimum of 19-20% for the degraded barley batch and 21-22% for the degraded maize batch.

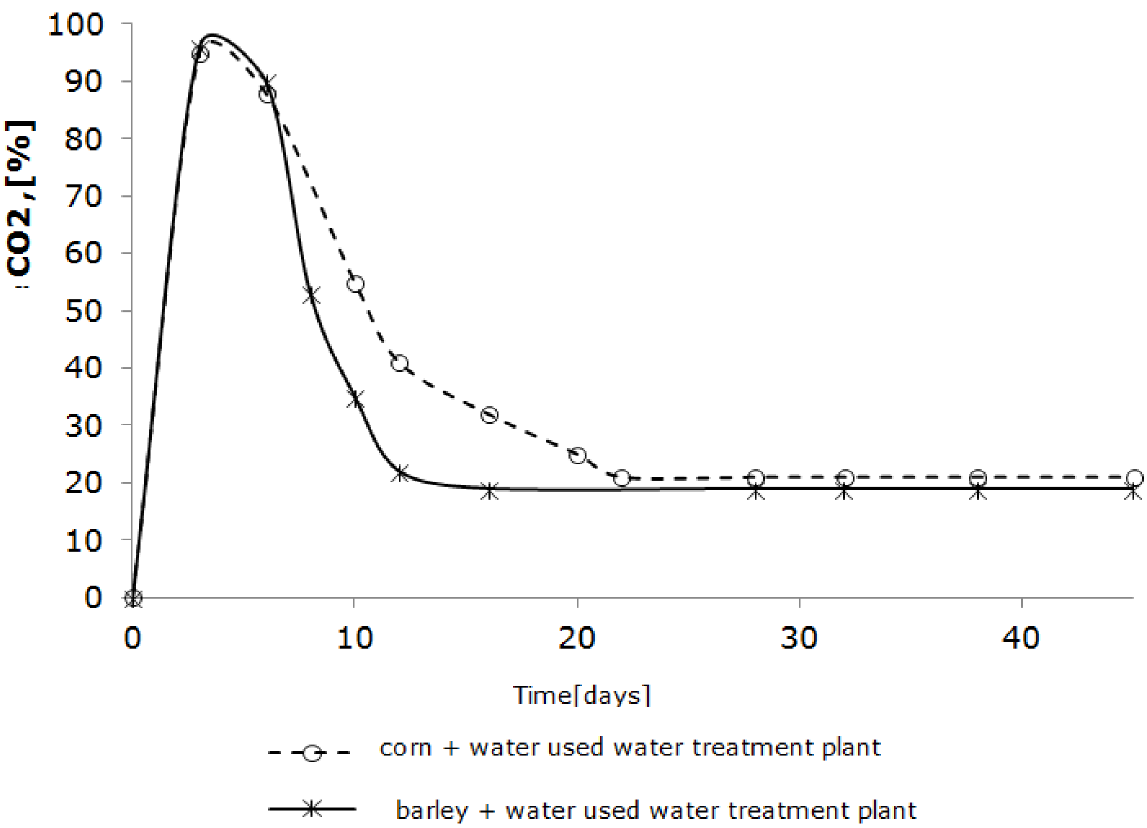


Figure C. 3.3. -CO_2 concentration variation

The quantities of biogas produced for the two materials in this first scenario are about 8.2 m^3 for charge containing degraded maize and approximately 11 m^3 for charge with degraded barley.

After completing the material test, the substrate analysis after the process took place.

In terms of methane production it may be mentioned that, for the charge containing degraded maize, about 14.1 m^3 was produced, while for the charge containing degraded barley about 18.1 m^3 was produced.

The following experiment involved the use of the same cereal materials in combination with wastewater from the brewery.

The process conditions were similar in terms of monitoring time and parameters observed during anaerobic fermentation (pH, temperature, pressure, partial biogas composition regarding the content of methane and carbon dioxide).

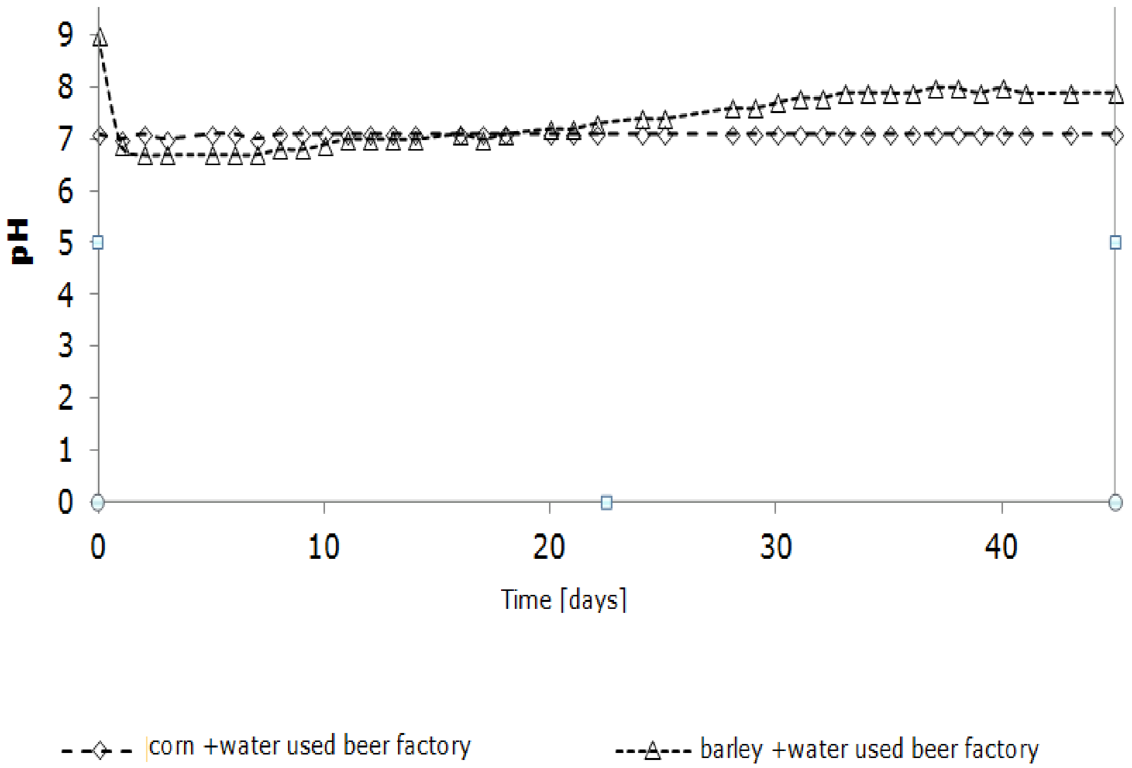


Figure C. 3.4 – Variation of pH for charges studied

In Figure C. 3.4. It can be observed that the pH for both ounces of material is stable throughout the process, presenting small variations at the beginning of the process due to the initial pH corrections for establishing a buffer element for maintaining as stable as the anaerobic fermentation process.

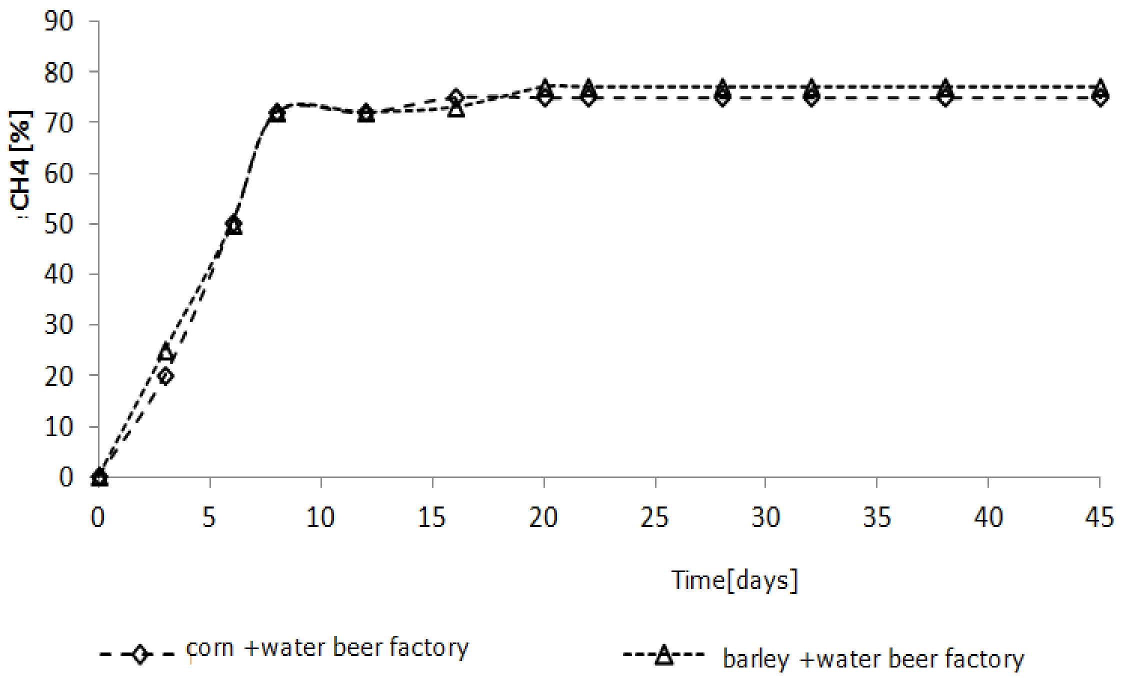


Figure C. 3.5 – Variation of the concentration of CH_4

From figure C. 3.5. it can be seen that the percentage of methane varies for both ounces up to approximately 75%, slightly higher for charge containing degraded barley and water from the brewery. From this perspective, both of the chosen materials present a behavior appropriate to the anaerobic fermentation process.

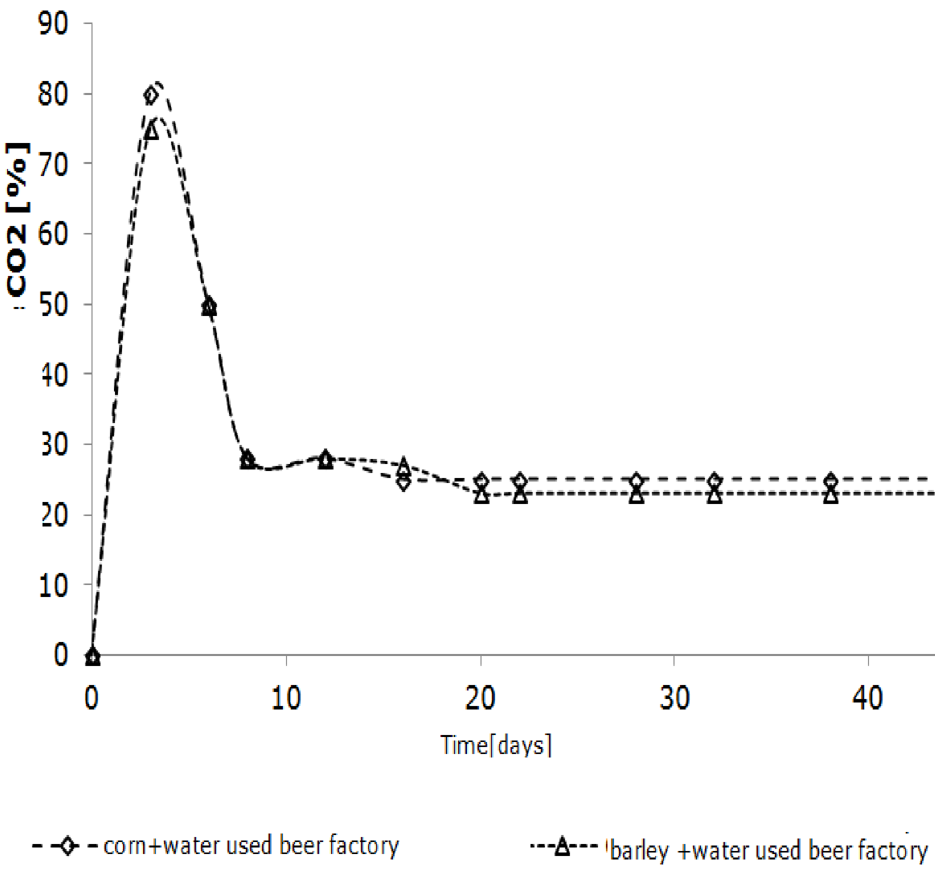


Figure C. 3.6. – The variation in CO_2 concentration

In Figure C. 3.6 it can be seen the inverse variation of the carbon dioxide concentration with that of methane, the minimum values achieved being for charge containing degraded barley, with concentrations of approximately 23 – 24%.

High carbon dioxide content is specific to this type of biofuel, but it impacts the subsequent combustion properties of biogas in different combustion plants.

The values obtained for laboratory determinations of the materials studied after the anaerobic fermentation process will be briefly shown in the following.

The following a comparison of the materials used in terms of the quantity of biogas produced during the anaerobic fermentation process will be achieved in the following

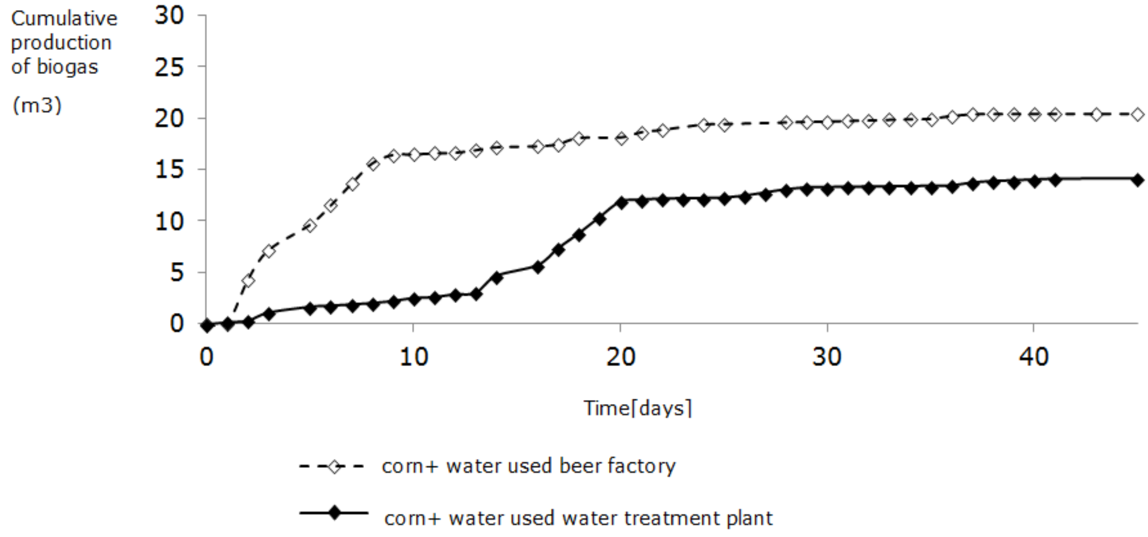


Figure C. 3.7 – Biogas production for charges with degraded maize

From figure C. 3.7 it can be observed that for the use of corn degraded as a tipping mass in anaerobic digestion processes, the specific charge with wastewater from the brewery has superior net results, making it a substrate suitable for this kind of lawsuit.

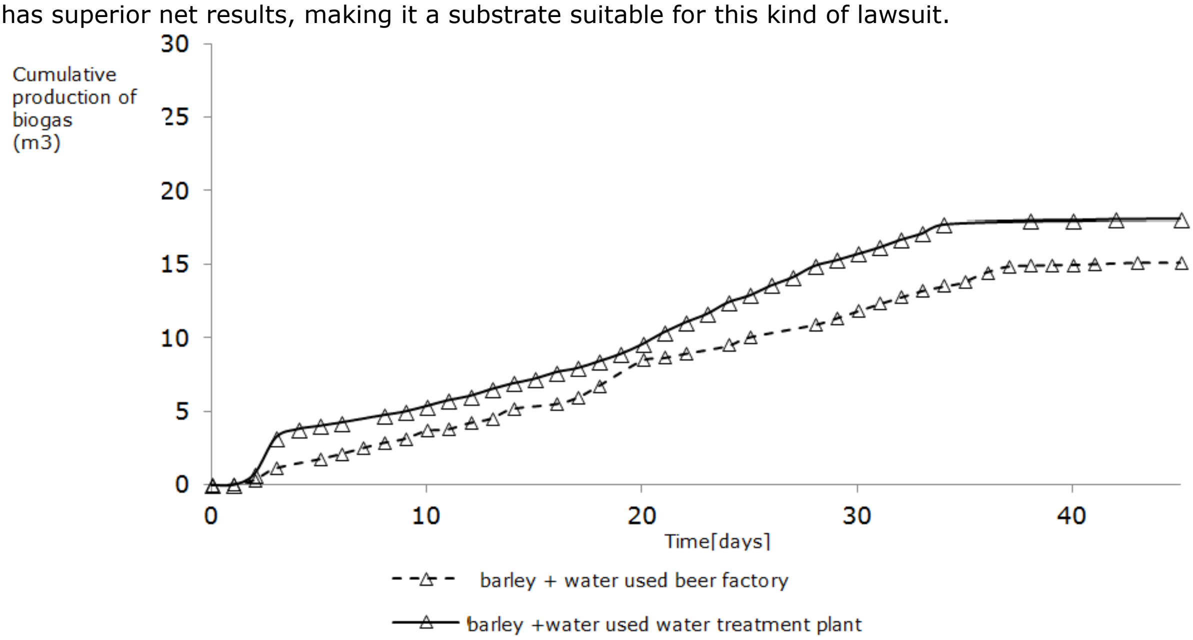


Figure C. 3.8-Biogas production for charges with degraded barley

It is notice that for charges that have used degraded barley, the best combination was with water from the sewage plant. Although there is not a very large difference in the amount of biogas produced, there is sufficient evidence to certify that for this type of cereal material, the combination of wastewater from the sewage plant is more conducive to the production of biogas good quality.

D. Energy recovery of waste, greenhouse gas emission reduction solution

In the PhD thesis, the environmental impact of the emissions of gases resulting from the elimination of waste to storage was analyzed. Methane and carbon dioxide emissions for different scenarios have been calculated. The scenario in which the commitments made regarding the storage of municipal waste, during the pre-accession period and accession of Romania to the European Union, were compared. These were compared with the emissions resulting from the scenario in which the landfill would have been made in accordance with the targets laid down in the legislation.

It was also calculated, for the following period until the year 2035, the possible impact on the quantities of greenhouse gases discharged into the atmosphere as landfill gases resulting from the disposal of waste by storage in the situation of compliance and non-compliance with the targets set by the EU.

1.The comparative analysis starts from comparing the quantities of CH_4 and CO_2 calculated using the LandGEM model [LandGEM], according to table D. 1.

Table D. 1. Centralization of data on quantities of CH_4 and CO_2 emissions for scenario I and II

	CH4 /Tons	CO2/ Tons
Scenario I	147705	331589
Scenario II	302558	676950

Graph D. 1. Represents the quantities of CH_4 and CO_2 estimated using the LandGEM model, in the case of the two scenarios, I and II. It is noted that the quantities of emissions have doubled in the case of the non-compliance scenario against the total compliance scenario.

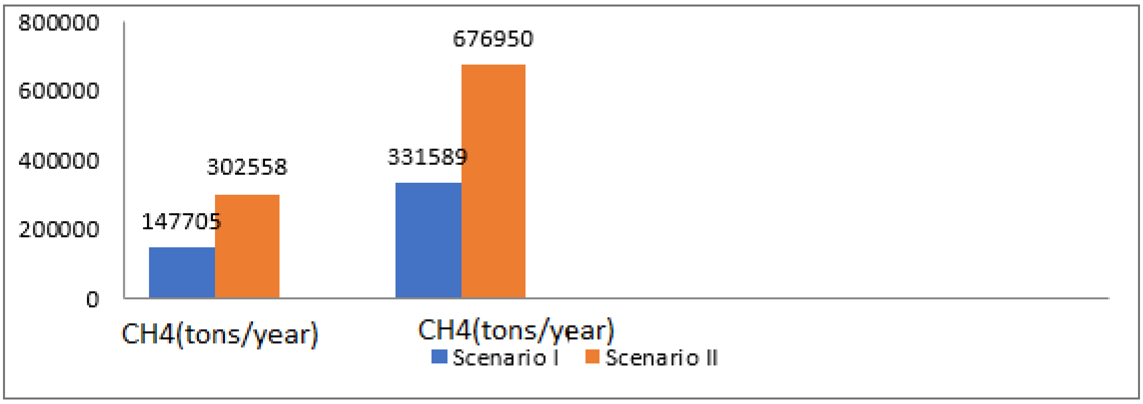


Figure D. 1. The graphical representation of the quantities of CH_4 and CO_2 calculated in the two scenarios (I and II),

1. The comparative analysis of the quantities of CH_4 and CO_2 emissions from waste storage in Romania in the coming years, calculated using the LandGEM model, is centralized in table D. 2.

Table D. 2. Centralization of data on quantities of CH_4 and CO_2 emissions for scenario III and IV

	CH_4 /Tons	CO_2/Tons
Scenario III	620000	1391800
Scenario IV	1502690	3373400

Scenario III was considered the scenario in which it is reduced the amount of waste eliminated for storage until the targets fixed for 2035 and scenario IV was considered the scenario in which it is maintained and in 2035 the amount of waste eliminated for storage at the current level.

It is noted that the amount of CH_4 that is discharged in the atmosphere by storing waste without respecting the European commitments in the field is 2.423 times higher than in the case of compliance with these obligations assumed. Therefore, by conformation the discharge of 882690 tones CH_4 could be avoid.

The amount of CO_2 that would be emitted in the atmosphere in case of non-compliance is 2.423 times higher than in the case of complying with European law. Therefore, the atmospheric emissions of 1981600 tones of CO_2 could be saved. If the quantities of CH_4 and CO_2 emissions are graphically eliminated for the two scenarios, the significant difference between these scenarios can be seen. Therefore, steps should be taken to reduce the amount of waste stored in the landfill and to eliminate them by other methods that reduce GHG emissions. Energy use of waste in biogas can be a sustainable solution.

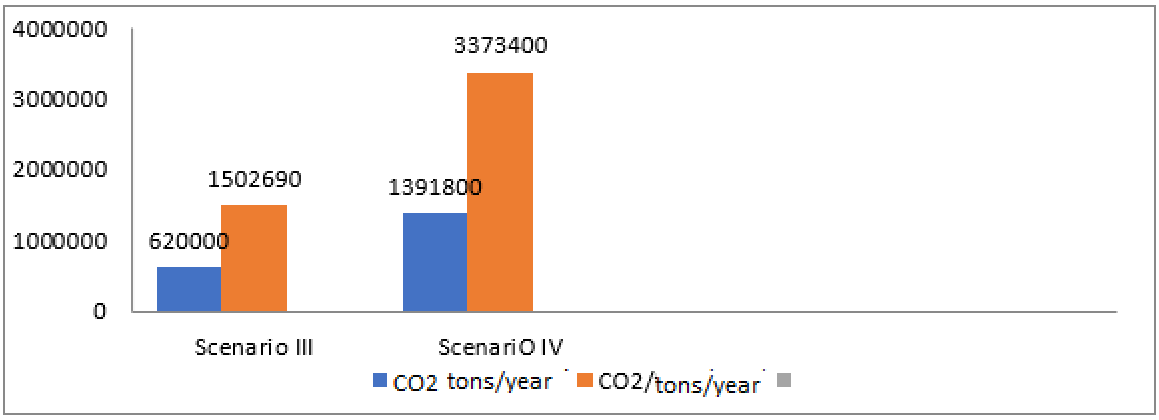


Figure D. 2. Graphical representation of the quantities of CH_4 and CO_2, scenarios III and IV

- The situation of compliance was also analyzed in which, up to 2035,the amount of eliminated waste for storage is reduced by eliminating it for recovery for biogas. In this case, it was estimated that it could be obtained by anaerobic digestion of these wastes in different co-substrates, 161 MW electricity. Greenhouse gas emissions that would be evacuated in the atmosphere for the production of 161 MW by burning conventional fuels were also calculated.

Thus it has been shown that the energy recovery of waste and the obtaining of biogas represents the waste management solutions that reduce the greenhouse gas emissions.

E. Conclusions and personal contributions

Studies and research carried out in the PhD thesis resulted in the formulation of the following conclusions and personal contributions to:

- The inventory of legislation on sustainable development, climate change, renewable energies, the circular economy, the recovery of municipal waste and the obligations incumbent on Romania to promote the production of renewable energies [23] greenhouse gas emissions [137], municipal waste management [29],

-Assessing the current state of knowledge on the anaerobic digestion of biomass, in particular organic waste, animal sewage and sludge, highlighting examples of good practice in the world but also in Romania,

-The experimental study on the identification of recipes for substrates from waste water in combination with various other organic wastes and their anaerobic digestion, which is determined by the establishment of a method of work both in theory and experimental to achieve the goal,

-The assessment of greenhouse gas emissions for various scenarios, in relation to the compliance with Romania's commitments on waste management and the promotion of energy production from renewable sources and the argument that the energy used of waste to biogas is a solution whose application would help to reduce environmental pollution,

- Making proposals for the directions of action to stimulate the energy recovery of biomass for biogas. These directions are:

1. Promoting the production of electricity and heat from organic waste by providing state aid to energy producers in the form of a fixed tariff for energy produced from biogas from the recovery of municipal waste, animal sewage, sludge, food waste, other wastes from agriculture;
2. Encouraging the improvement of methane quality in order to be used as fuel and encouraging the use of methane in transport. This legislation would create the conditions for compliance with the European directives establishing that, by the year 2020, 10% of the fuel used in transport was biofuel;
3. The establishment of quality digestate resulted from anaerobic digestion in biogas plants and setting conditions for its use as fertilizer;
4. Stimulating the use of digestate as fertilizer by giving incentives to agricultural producers producing bio products and using natural fertilizers that have no negative impact on the environment;
5. Promoting and developing research projects for the transfer of technologies from countries that have applied waste recovery projects to biogas and the recovery of biogas for the production of renewable energy and for its use as biofuels.

Through the research carried out and by the personal contribution made in the PhD thesis, there has been demonstrated that the technologies for the recovery of biomass to biogas are the solutions to reduce the environmental pollution caused by the management of organic waste and those resulting from socio-economic activities. The application of these technologies creates the conditions to reduce the environmental pollution and to comply with the commitments undertaken by the transposition of European legislation in the Romanian law.

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