Biogas production based on agricultural residues. From history to results and perspectives

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Abstract: - The paper focuses on the practical behavior of different types of agricultural matter during the anaerobic fermentation process. First a historical development is highlighted in the idea that from the beginning this process was meant to serve the energy development from available natural and diverse resources. One of the main features that influence the fermentation process is the degradation of the initial material used. The final stage of the anaerobic fermentation process contains material in different stages of decomposition, as function of temperature and type of biomass residue. The potential of Romania is shortly described as well. The second part is dedicated to experimental demonstrations of the process, in brief. All the measurements were accomplished on a small – scale, simple, installation designed special for the research upon the biogas production from agricultural waste.

Key-Words: - agricultural residues, anaerobic fermentation, small - scale installation, degradation process

1 Introduction

The global energy demand is growing rapidly, and about 88 % of this demand is met presently by fossil fuels. As statistics indicate, the most common types of fossil fuels that are used in present are oil and their products, natural gas and coal.

Scenarios have shown that the energy demand will increase during this century by a factor of two or three, as result of the population growth and energy consumption per capita. At the same time, concentrations of greenhouse gases (GHGs) in the atmosphere are raising rapidly, the fossil fuel-derived CO_2 emissions being the most important contributor. In order to minimize related global warming and climate change impacts, GHG emissions must be reduced to less than half of global emission levels of 1990. Another important global challenge is the security of energy supply, because most of the known conventional oil and gas reserves are concentrated in politically unstable regions [1].

It is estimated that in terms of primary source used, by 2030, the structure of energy production will be based on: 75-85 % of conventional fuel combustion, 10-20 % of nuclear fission, 3-5 % of waterpower, approx. 3 % of solar and wind energy [2].

By 2020 renewable heat solutions as alternative to fossil based systems should be provided for almost each type of consumer. These solutions should be technically reliable, environmentally sound and economically attractive. The biomass market share should rise from 11 % in 2007 to about 25 % in 2020, taking into account a reduction of heat demand.

With exception of hydroelectricity and nuclear energy, the major part of all energy is produced from petroleum, charcoal and natural gas. However, these sources are limited, and will be exhausted by the end of this century [3].

As a consequence of both public and economical pressure, the energy sector and also chemical, metallurgical etc. industry are undergoing considerable changes to face the swiftly growing need for the use of cheaper and widely available resources. Currently, renewable energy resources, among which are the well-known solar, wind, hydro, wave, geothermal and biomass represent about 14 % of primary-energy consumption in the world, with biomass being the major contributor with approximately 10 % [4].

In short term (2020) vision, it is essential to develop alternatives to fossil fuels for all markets of heat/cooling, electricity and transport. It is particularly critical for heat because private consumers, especially with lower incomes, will suffer very much when oil prices will rise again in the future. Industries and district heating plants as well, need to be prepared to diversify their energy supply towards more environmentally friendly fuels. In all fields lowest emissions and ease of handling will be essential for high acceptance.

The most common forms of renewable energy are considered the solar, geothermal energy, water, wind and finally the biomass related energy. Some of the most important benefits of using renewable energy are based on the organic composition, lack of fossil driven CO_2 emission, does use mainly locally available resources and are solutions for all needs [2], covering best and directly the local community.

The utilization of renewable energy resources will lead to the rise of working opportunities offer on local and regional level; this field of activity is ensured by approximately 350.000 of working places within the EU in present [8].

In 2030 it is probable that biomass will be an outstanding solution for individual heating, dominated by pellets in urban areas and by wood chips, wood logs and pellets in rural areas. The boilers and stoves markets will progressively shift from oil based system to biomass based system. Heating oil will progressively disappear because of unaffordable prices. Micro co-generation of heat and power based on biomass will be progressively available in all sizes even at household level and for nearly all part load cases. Most district heating and cooling system will be retrofitted to solar thermal, biomass and geothermal and many new small heats cool and biogas networks will appear.

The importance of the biomass resources was recognized and has increased enormously in the frame of energy systems. This is not only based on the current development of growth of public environmental awareness and their outer appearance, but also on the fact that the biomass energy is the only renewable energy achieving continuous power, as a result of planning and storing the available energy resource [5].

Fermentation to a combustible biogas is an alternative route for wet based raw biomass. Biogas can be burned directly in a boiler for heat or an engine for co-generation, while upgraded biogas (methane) can be injected in the natural gas grid and used directly at the consumer in boilers or small CHP.

There are two major streams of biodegradable wastes: (i) ***green waste*** from parks, gardens etc. and (ii) ***kitchen waste***. The former includes usually 50-60 % water and more wood (lignocelluloses), the latter contains no wood, but up to 80 %, by mass, water [6].

Bio-energy from renewable resources is already a viable alternative to fossil fuels; however, to meet the increasing need for bio-energy several raw materials have to be considered. Ligno-cellulose is the most abundant organic material on earth, in diverse quantities, qualities and forms, and is therefore a promising raw material for bio-energy production [7].

Different technologies are developed presently for the energy recovery of all types of wastes, one of them being the anaerobic fermentation process, which has as main product the biogas, considered a CO_2 neutral gaseous fuel.

Not all agricultural and food processing wastes have a high organic content that is amenable to biological treatment. Those with low organic content, insufficient nutrients, and which contain toxic compounds, require supplementary physical-chemical treatment, such as settlement, pH adjustment, chemical precipitation, coagulation, reverse osmosis, ion exchange, or adsorption. However, biological treatment, particularly anaerobic, is often the best and/or most cost effective alternative for economical pretreatment [9].

Anaerobic digestion and biogas production are promising means of achieving multiple environmental benefits and producing an energy carrier from renewable resources. Replacing fossil fuels with biogas normally reduces the emission not only of greenhouse gases, but also of nitrogen and sulfur oxides, hydrocarbons, and particles [10].

Anaerobic digestion consists of a series of processes in which microorganisms break down biodegradable material in the absence of oxygen, used for industrial or domestic purposes to manage waste and/or to release energy. It is widely used as part of the process to treat waste water. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere.

Anaerobic digestion is widely used as a renewable energy source because the process produces a methane and carbon dioxide rich biogas suitable for energy production, helping to replace fossil fuels. The nutrient-rich digestate which is also produced can be used as fertilizer. The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids.

Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The technical expertise required to maintain industrial scale anaerobic digesters coupled with high capital costs and low process efficiencies had limited the level of its industrial application as a waste treatment technology.

Biogas is considered to become one of the most important alternative fuels and will potentially replace partially natural gas and oil. No negative or limited environmental side effects are observed, because biogas can be produced from all types of "green" biomass [11].

Romania is the thirteenth country in Europe as size (238,391 km^2 area) and, according to statistical data from 2006, has a population of about 20.6 million inhabitants. Natural resources represent an essential part of Romania's richness and the exploitation of these resources, both renewable and non-renewable, should determine the level of the social and economic development of the country, its environmental status and living and financial standards of the population. In order to contribute to the quality of life in Romania, natural resources need to be exploited in a more sustainable development manner [12], according a strategy that should not remain only a legal vision, but should implemented, especially by creating economic chains from resource owner to end-user.

Figures 1 and 2 present the potential of biomass from wood and agricultural waste in Romania.

Presently, technology to make benefit of the available potential is not commonly used. Spectacular results for vegetable waste (cellulose) utilisation, in the absence of an adequate technology, are missing, even if raw material is available in considerable quantities.

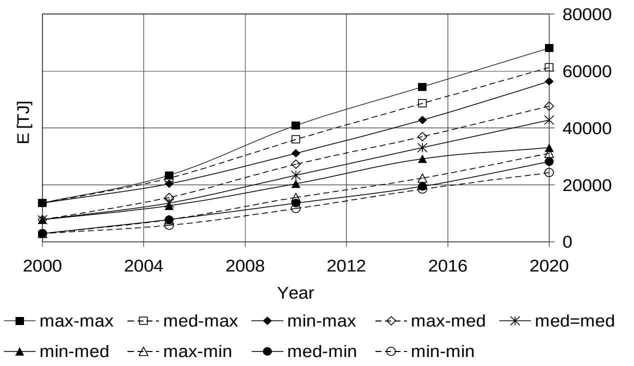

Fig. 1 – Biomass potential from wood residues [18]

Because global orientation on the exploitation of renewable energy is very important, Romania, as a member of the European Union and as a source of untapped potential of renewable resources, is to present current existing alliance. It is evident that presently there is a remaining potential of renewable sources, of which a large proportion is occupied by biomass, both timber and agriculture, for which the necessary technologies to exploit it.

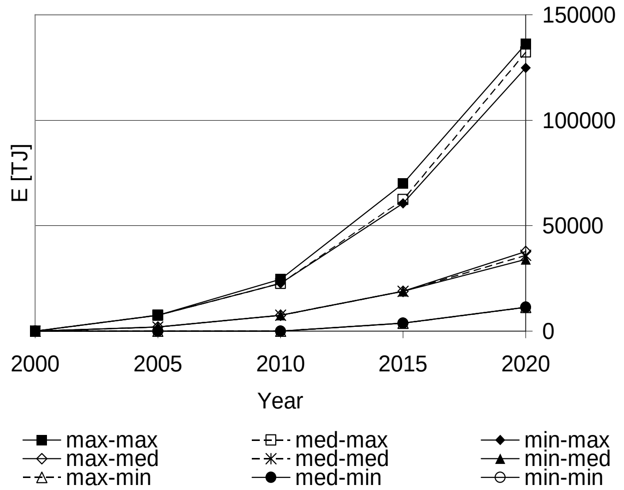

Fig. 2 – Biomass potential from agricultural residues [18]

Figure 3 presents the energy potential distribution in Romania.

Fig. 3 – Energy potential distribution in Romania [19]

It can be observed that our country has a great potential both from agricultural and wood biomass.

2 History of the biogas

Ancient Persians observed that rotting vegetables produce flammable gas. In 1859 Indians built the first sewage plant in Bombay. Marco Polo has mentioned the use of covered sewage tanks in China. This is believed to go back to 2,000–3,000 years ago in ancient China. This idea for the manufacturing of gas was brought to the UK in 1895 by producing wood gas from wood and later coal. The resulting biogas was used for gas lighting in street lamps and homes.

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of bio-fuel. One type of biogas is produced by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and energy crops. This type of biogas comprises primarily methane and carbon dioxide. The other principal type of biogas is wood gas which is created by gasification of wood or other biomass. This type of biogas is comprised primarily of nitrogen, hydrogen, and carbon monoxide, with trace amounts of methane.

The gases methane, hydrogen and carbon monoxide can be combusted or oxidized with oxygen. Air contains 21% oxygen. This energy release allows biogas to be used as a fuel. Biogas can be used as a low-cost fuel in any country for any heating purpose, such as cooking, etc. It can also be used in modern waste management facilities where it can be used to run any type of heat engine, to generate either mechanical or electrical power. Biogas can be compressed, much like natural gas, and used to power different energy chains. It is a renewable fuel, so it qualifies for renewable energy subsidies in some parts of the world.

Biogas typically refers to a gas produced by the biological breakdown of organic matter, in absence of oxygen. Biogas originates from biogenic material and is a type of bio-fuel [19]. Biogas arises from decomposition of organic substance, by means of bacteria, in anaerobic or aerobic fermentation processes [11] [13]. Organic matter consists mainly of water, albumin, fat, carbohydrates and minerals and together with bacteria; they decompose the original components, carbon dioxide, minerals and water. Thus a mixture of gas, called biogas, arises as a metabolic product. Flammable methane (CH_4) is the main component of biogas, with a percentage of 50-85 % by volume, and thus represents the main source of energy.

This natural process of decomposition occurs only in anaerobic environment, i.e. only when oxygen is absent. The decomposition process is called decay in this case and is naturally occurring in swamps, lakes, etc. In case of oxygen presence, decomposition is carried out by other bacteria; the term for this process is *rotting* or *composting.* Microorganisms that generate methane production are called methanogenic microorganisms, of liquid and acidogene origin. The mechanisms that occur and develop along the stages features are based on acetogene of type B and C. The energy released in the anaerobic decomposition process is transferred as energy heat in the form of composting, and it is used by bacteria to form methanogenic flammable methane molecules.

Collected and stored in the biogas, the energy is of renewable nature, being derived from organic matter of the green plants. More and more, the fossil energy will be less used and replaced, alternatives are becoming necessary and the use of biogas is becoming increasingly important. The exploitation of biogas energy is, opposed to burning natural gas, liquefied gas, oil and coal (all containing fossil C), CO_2 - neutral, because the resulting carbon cycle circuit is closed as it is reused by green plants during their growth, under sunlight, within the photosynthesis. This prevents and limits the increase of the atmospheric CO_2 concentration [14].

The use of waste water and so-called renewable resources for energy supply is not a novelty, with evidence of such practices even before Christ's birth. Even around 3000 BC, Sumerians practiced anaerobic waste cleaning [17]. Old Roman scholar Plinius described around 50 years BC lights that glittered phenomena, in the ponds area.

By 1776, Alessandro Volta personally collected gas from the atmosphere over the Lake Como, in order to analyze it. His research showed that the formation of gas depends on a fermentation process and can even form an explosive mixture with air. English physicist Faraday made experiments with swamp gas and identified a type of hydrocarbon in its composition. Later, around 1800, Dalton, Henry Davy described the first chemical structure of methane. The final chemical formula was elucidated by Avogadro in 1821.

In the second half of 19th century, in France, a systematic and scientific research for a better understanding of the process of anaerobic fermentation started. The objective was to remove bad odor emanating from waste water. During investigations, the researchers have detected typical microorganisms that are retested nowadays as essential for the fermentation process. Bechamp identified by 1868 that a mixed population of microorganisms is necessary to convert ethanol to methane, since more final products were formed by the fermentation process; the whole process depends on the substrate used.

By 1876, Herter reported the presence of acetate in the waste water, forming methane and carbon dioxide in stoichimetric amounts. Louis Pasteur tried by 1884 to produce biogas from horse droppings, collected from the streets of Paris. Together with his students he managed to produce 100 m^3 of methane from a fermentation process, developed at 35 °C. Pasteur explained that the rate of production is sufficient to cover energy needs for street lightening in Paris. Practically, this is considered the starting point of larger application of renewable energy.

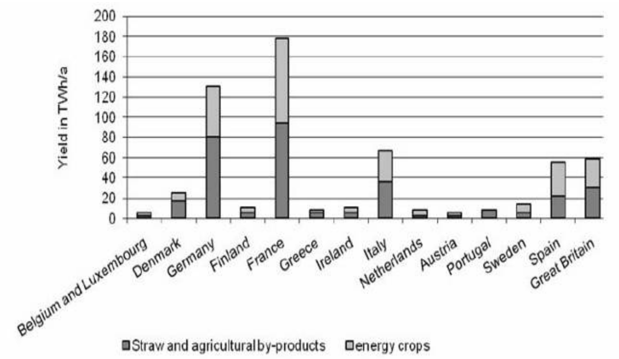

Fig. 4 – Biogas production in Europe [17]

Figure 4 presents the biogas production in Europe, observing that most developed countries in this regard are France, Germany, Italy, Britain and Spain, while Denmark and Sweden do not put as much emphasis on the use of biogas, in those countries using of other types of other renewable energies (wind, solar) being considerable more favorable.

In Figure 5 the expansion of biogas in Germany is presented, and Figure 6 underlines the biogas development in China, by the number of plants built between 1972 and 2006. The differences are obvious, in respect to specific figures per capita, and explained by the difference in technology level, that is more and more reduced.

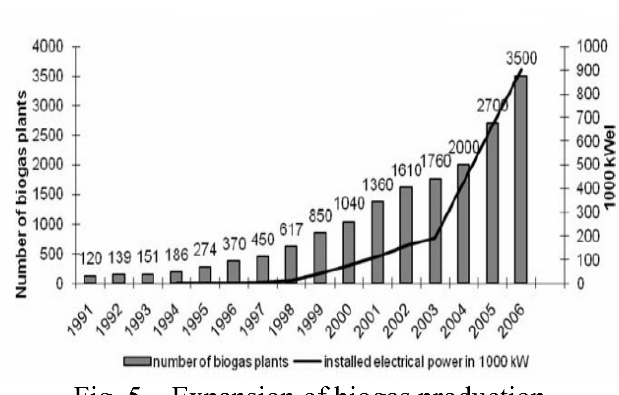

Fig. 5 – Expansion of biogas production in Germany [17]

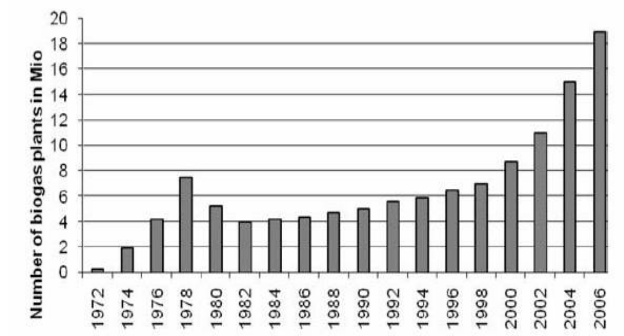

Fig. 6 – Expansion of biogas production in China [17]

3 Biomass – the renewable source for obtaining biogas

Biomass is the only renewable energy source that can be transformed into gas, liquid or solid fuel by special conversion technologies, according updated knowledge. This universal renewable energy carrier can be used in a wide range of applications, in the energy sector, for small scale but also larger applications. Presently it is possible to provide this renewable resource for the whole range of applications that require energy input, starting from heating stations until providing electricity to mobile applications for transport. On average, the industrialized countries contribute to the total biomass energy sources used in a proportion of 9-13 %, while in developing countries it contributes in a percentage ranging from 5 % to 30 % [15].

Typically, after the biomass was treated, it is transformed into one of the major energy forms: (i) Electricity or (ii) Heat.

Range of application and disposal of biomass form the two, very important advantages of biomass. Another major argument for using the energy resources originated in bio - resources is the possibility of protecting the environment and climate. When stored in biomass energy use, greenhouse gases like carbon dioxide are emitted, but this amount is not a supplementary generated product, as it is result from a natural decay processes. Thus bio-energy carriers can be considered neutral in terms of climate damage, particular CO_2 emission.

The Eurostat balance sheet (Figure 7) gives a view of the 2007 situation. 98 Mtoe biomass are used in Europe and about 1/3 are used in electricity, CHP and DH plants, while the rest is being used in households and services, industries and Bio - fuels. Altogether biomass for heat (households, services, industry) and derived heat from biomass amount to 61 Mtoe out of 78 Mtoe final bio-energy consumption, 98 Mtoe gross inland consumption of biomass and 116 Mtoe renewable. It means biomass for heat and derived heat from biomass represent roughly 4/5 of the final bio-energy, 2/3 of the biomass consumption and 55 % of all renewable energy sources (RES). It also covers 97 % of the renewable heat production.

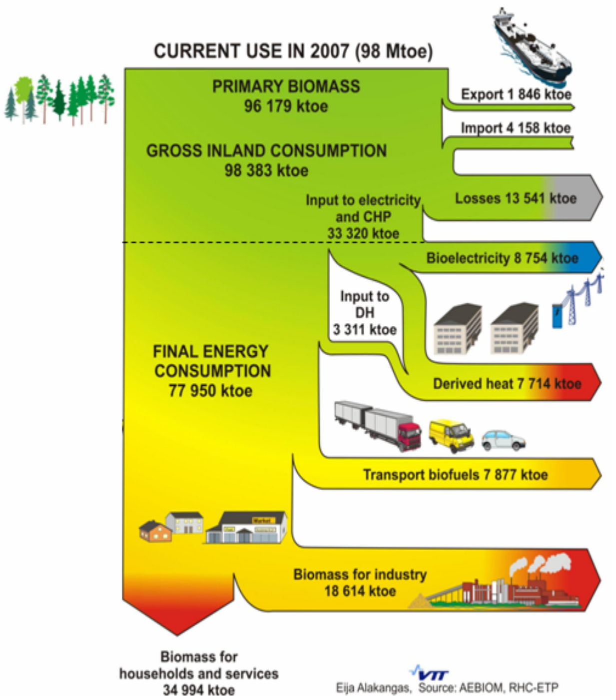

Fig. 7 – Bio-energy balance sheet [20]

Plant biomass is generally found in form of solid aggregates with water content, and, in most cases, for technical reasons, this is removed when the use for energy production is focused. It is possible to create a useful product with bio-energetic properties only by correct processing. This enables changing the state of aggregation and to allow the use as renewable fuel in conventional process. The sources of bio-energy are always classified according to the state of aggregation: solid, liquid, or gaseous. They are used in bio-energy and energy conversion facilities or even combustion engines. Engines and fuel cells - which are currently in progress research stage - are unable to use solid bio-energy sources, as furnaces, stoves or plants, working in combined or cogeneration systems for heat and power production are.

Form and aggregation state of bio-energy products processed are determined by the applied conversion technologies. Different equipments such as engines, for example, are operating under various techniques, which are optimized for the particular conditions and quality of sources of bio-energy.

3.1 Solid bio-energy sources

The largest group of solid bio-energy sources includes products made from wood. They are derived from industrial processing of wood waste. In many areas of agricultural by-products such as straw, are also used to generate energy from biomass.

On one hectare of straw cereals (Figure 8) have an energy content of 73 GJ. It is approximately equivalent to 200 liters of oil. However, straw and other products in this category have different combustion characteristics from those of woody fuels. Point transformation in ash and emission behavior of biomass type straw means that different technical approaches are needed.

Fig. 8 – Cereal straw [16]

Fig. 9 – Residues of wood material [16]

Another important category of waste, which is not necessarily part of the old wood sector, represents the wood residues from environmental management. In Figure 9 various wood residues are highlighted. These occurred during maintenance work on roads and canals, parks and care. Wood residues from environmental management are usually a mixture of wood, leaves and straw type products. Only very rarely it is possible to consider these mixtures for a new final product, thus utilization of its energy content is a very good strategy.

3.2 Liquid bio-energy sources

Mobility is essential in industrialized society. With few exceptions, passenger transport and freight are based on liquid fuel. Today, there are few alternative bio-fuels for these tasks. Ethanol, the alcoholic fermentation and methanol produced from cellulose can be considered as having a biomass origin. By far, the most common are rapeseed and sunflower (Figure 10). Results of these two oils are used either naturally or as bio-fuel.

Fig. 10 – Sunflower plant [16]

Being considered CO_2 neutral fuels derived from liquid bio-energy sources, they are characterized by low emission and lower potential pollution. By comparison, they are inferior to fossil fuels as the performance, but much friendlier considered for the environment.

3.3 Gaseous bio-energy sources

The gaseous bio-energy sources result from natural biomass conversion. They are produced using microbiological processes such as anaerobic fermentation, but also by thermo-chemical conversion of solid biomass gasification process.

Biogas is created without the action of oxygen during fermentation of biological material of animal and plant type. In this case, the symbiosis of bacteria will break the ties resulting mainly methane gas and carbon oxides. In practice, this occurs in agricultural biogas plants. In Figure 11 a model of installation built in order to produce biogas from different types of biomass wastes is presented.

Thermo-chemical conversion of solid into gaseous fuels (renewable bio-energy) takes place during the process of gasification. Chains of carbon fuels will create carbon monoxide gas, hydrogen and reduced quantities of methane.

Fig. 11 – Biogas installation [16]

In conclusion, one stresses by this short out view that bio-energy is very important at this moment for the global strategy of a sustainable development, which occurs in different aspects, and that biogas, represents, among different options, a solid strategy, that should be applied, both in small and larger scale.

4 Small - scale installation description and functioning

Figures 12 and 13 present a picture of the small - scale installation and its schematics to underline the technology used for biogas production. One stresses out that the anaerobic fermentation reactors consist of bubble glass vessels, resistant to variations of temperature, and pressures of 0.5 - 0.6 bar, having a useful volume of about 2 Liters. To ensure that gas washing occurs within the reactors, they are connected through flexible tubes with two heat-resistant glass containers (the two vessels from the middle), with a useful volume of 0.5 l containing approximately 200 ml of water. The gas formed trough anaerobic fermentation will thus pass through the flexible tubs to the bottom of small vessels and the impurities are washed out.

Fig. 12 – Photo of the small - scale installation [19]

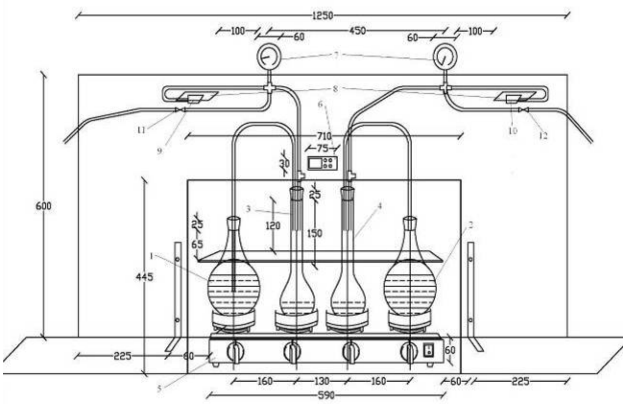

Fig. 13 – Small – scale installation schematics [19]

To avoid the mal function of anaerobic fermentation process, the reactors will be covered with opaque material. Given the fact that lack of homogenization by mixing the suspension can lead to inhibition of the process by developing a film on the surface of the upper part of suspension, each of the two reactors contains a magnet and the agitation occurs through a magnetic stirrer, with adjustable speed (Figures 14 and 15).

Fig. 14 – Magnet located at the bottom of the glass vessel [19]

The stirring process is developed on a daily basis, to ensure proper mixing of material inside glass vessels. The obtained biogas is deposited inside two special gas bags for further analysis (Figure 18).

Fig. 15 – Magnetic stirrer [19]

In Figures 16 and 17 are presented the system composed of the temperature controller and the thermocouple (type J).

Fig. 16 – Temperature controller [19]

Fig. 17 – Type J Thermocouple [19]

Fig. 18 – Biogas storing special bag [19]

Figures 19 and 20 present the samples of biomass used during the experiments.

Fig. 19 – Maize bran [19]

Fig. 20 - Recipe of maize, corn and sunflower seeds [19]

The waste materials used for experiments were maize bran and a recipe of maize (40 %), corn cobs (40 %) and sunflower seeds (20 %), all percentage by mass.

Because the installation allows the parallel work with two different types of material, the measurements were accomplished in parallel, for both series of experiments. After the completion of the anaerobic fermentation process, pictures related to detailed aspect of material, transformed as result of the influence of degradation, were taken.

5 Experimental part and discussion

The experiments were accomplished using a temperature domain of 30 – 38 °C and the duration for each batch extended over 45 days.

Before the experiments, preliminary determinations for each type of biomass were completed and the results are presented in Tables 1, 2 and 3. Table 1 presents the general characteristics for the two biomass batches, Table 2 presents the major elements that are found inside the two batches and Table 3 presents the composition in heavy metals for the two batches.

Table 1 – General characteristics for the biomass batches – water ash free material [19]

No.	**Sample**	**Hygroscopic Humidity [%]**	**Ash content [%]**	**Low calorific value [kJ/kg]**
1	Maize bran	0.16	4.63	15.535
2	Recipe of corn maize and sunflower seeds	1.04	1.81	15.192

Table 2 – Major elements for the biomass batches – waster ash free material [19]

No.	**Elem.**	**Maize bran [mg / kg]**	**Recipe of corn, maize and sunflower Seeds [mg/kg]**
1	Mg	1331	764
2	Al	71	61
3	Si	174	34
4	P	5855	2419
5	S	1165	925
6	Cl	370	388
7	K	9697	4359
8	Ca	1209	901
9	Mn	108	14
10	Fe	177	117
11	Zn	69	25

Table 3 – Heavy metals for biomass batches – water ash free material [19]

No.	**Elem.**	**Maize bran [mg / kg]**	**Recipe of corn, maize and sunflower seeds [mg/kg]**
1	Cr	0.919	8.034
2	Mn	184.127	27.236
3	Co	1.385	0.866
4	Ni	1.494	4.789
5	Cu	6.053	-
6	As	0.366	-
7	Se	0.833	-
8	Br	5.472	10.836
9	Sr	7.256	2.819
10	Cd	4.102	3.905
11	Sn	-	0.387
12	Hg	-	-
13	Pb	6318	8.02

In Figure 21 the temperature variation during the anaerobic fermentation process for both batches is presented.

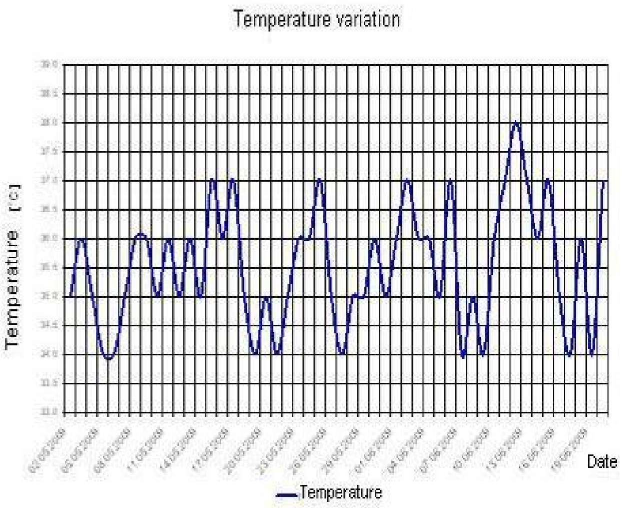

Fig. 21 – Temperature variation for the anaerobic fermentation process [19]

The considered regime that is used in our case is the mesophilic one, with values of temperature inside the range of 30 – 38 °C. The real variation of temperature was of 34 – 37 °C, which means that the process was fully under control. In the next Figures (22-29) microscope images of the two batches, after the ending of the anaerobic fermentation process, are presented, at different magnification rates, for comparison.

In order to confirm that the process of fermentation took place, the characteristic smell was confirmed, both during the monitoring period and when emptying the vessels. According to literature ([17][19]), the smell is one of the specific issues standing for the fact that are still unresolved matters concerning anaerobic fermentation process. It is also an evidence of the presence of hydrogen sulfide in the gas composition, and also a sign connected to and attesting the material degradation process.

Fig. 22 – Detail of recipe batch: magnification 20 times

Fig. 23 – Bacterial hallo around a piece of corn cob: magnification 30 times

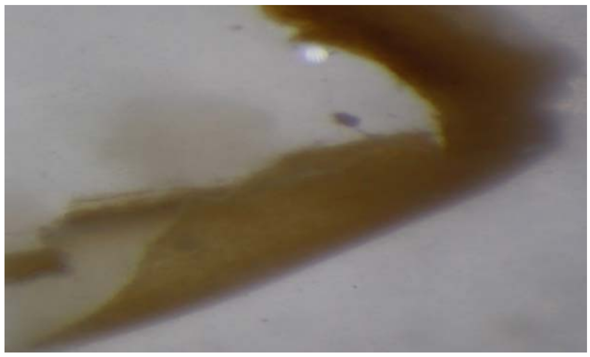

Fig. 24 – Part of degraded piece from maize bran: magnification 30 times

Fig. 25 – Bacterial hallo on maize bran degraded material: magnification 60 times

Fig. 26 – Detail of maize bran structure: magnification 60 times

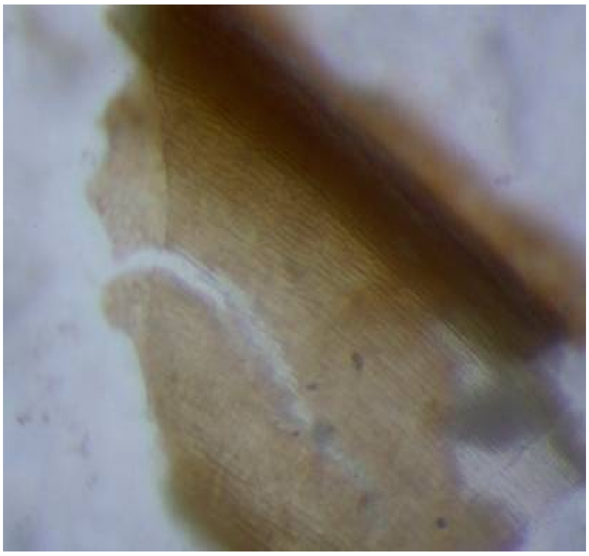

Fig. 27 – Deterioration of maize bran structure: magnification 80 times [19]

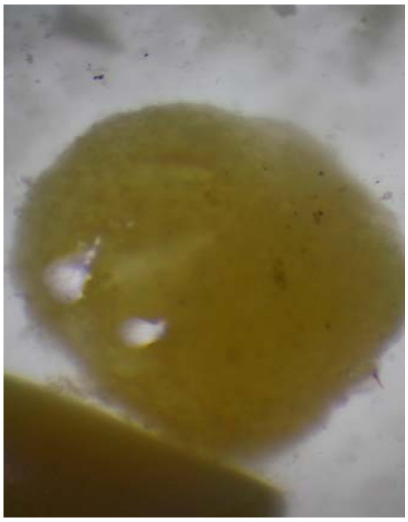

Fig. 28 – Detail – Impurities inside of the recipe batch: magnification 60 times

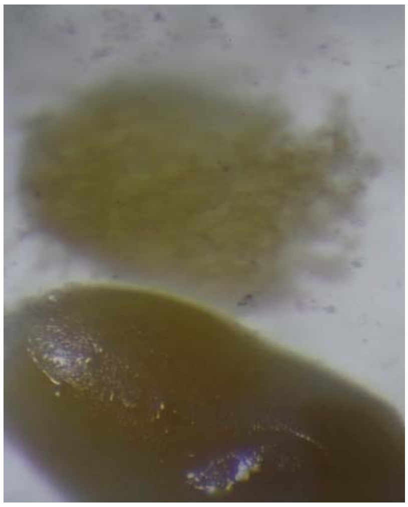

Fig. 29 – Hallo and impurities around the fragment of corn cob inside the recipe batch: magnification 100 times

For the first batch, the images (Figures 22 and 23) underline, at an enhancement of 20 times and 30 times, the hallo of bacterial population (with white color) inside the suspension and also the relative degradation of the material.

The second batch, presented in Figures 24 and 25, shows a more resistant structure over the degradation process, because bran is a more fibrous material. Also, in this case, one observes the presence of bacterial hallo and the partial degradation of the material.

Figures 26 and 27 underline the close-up on the main structure for the maize bran batch, together with the different stages of structure degradation, presented as ruptures inside the material.

Figures 28 and 29 put into evidence the partially degraded structure for the recipe batch, and also, in close detail, the impurities and partially formed hallo around the components of the recipe.

One concludes that the process, even if it reaches the final stages, does not degrade the entire mass of material (phenomena attested in both batches), fact that can be useful in using the rest o material for further utilization, after complete component and energy content analysis especially, in case of larger quantities.

6 Conclusion

One demonstrated that anaerobic processes for biogas generation are possible also using waste material input, of bio-origin.

Biogas represents one of the most important sources of energy that can be used in order to recover, in large, medium and small scale installations, by means of clean technologies, mostly the entire energetic potential of wastes. Bio-energy is an inexhaustible energy resource ready to be used for second level energy production, both by anaerobic fermentation and other processes (aerobic fermentation, gasification) that represent related technologies for anaerobic fermentation process, being used presently.

The nature of utilized biomass represents an important factor in the production of biogas, supplementary to the quantity and quality of the produced biogas using the anaerobic fermentation process.

The energy density of biomass is less than classic fossil fuels and creates non-economic aspects, including especially transport, if it is not used in the vicinity area. Therefore, it is recommended to be valued at production place, in small or medium plants, located nearby, in the area where the bio main initial matter is located naturally or in cultivated form.

The requirements for biomass preparation in order to transform the energy content into biogas are dictated by its sources, as the quality of raw materials can vary widely in terms of physical-chemical characteristics and hence the energy transformation. The main operations which have to be accomplished are: (i) preliminary size reduction, (ii) transport and storage, (iii) removing of non desired materials, and, in some cases, (iv) reducing the ash content, finally (v) total or partial drying and secondary size reduction, prior to the use.

The main parameter to be controlled during the anaerobic fermentation process is temperature, the chosen range having a relevant impact on the characteristics of the resulted biogas. Also, as demonstrated by the experimental approach presented – based on the small scale installation –stirring of the material is also important, on a regular basis, because, by this way, the material becomes homogenous and no risk of molding might appear.

Further parameters of influence on the anaerobic fermentation process are complementary to the temperature at which the process is achieved: the pH of slurry, the elementary chemical composition of the materials used and the biomass nature. As it resulted from the details involved in the process of anaerobic fermentation, the material can be decomposed partially, or totally, as a function of its nature and properties.

The residue from the anaerobic fermentation should be used for further purposes and might be subject and origin to develop different methods, other than the existing ones, for using the full potential of the biomass used as input.

Research in the field is at any time necessary, as it must support the economic studies and forecast with real data. For the future one suggest the enhance of

- Studies concerning the production and market potential with sustainability criteria.
- Development of cost-efficient, high quality fuels from various biomass sources – e.g. via pretreatment, blending, etc.
- Development of agro-to-energy and forest-to-energy chains.
- Development of agricultural practices and forest practices of biomass produced from crops and other additional biomass sources, including energy plantation (short rotation).
- Develop regional bio-energy concepts for the whole chain (e.g. biomass or green village/community/region).
- CO_2 reduction and development of carbon negative solutions (bio-char as future soil improver).

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