EUROPEAN JOURNAL OF LIFE SAFETY AND STABILITY (EJLSS)
ISSN2660-9630
www.ejlss.indexedresearch.org Volume 23, November-2022 ||

Processing of Fallen Leaves to Produce Ecological Clean Gas

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Abstract: *The possibility of recycling fallen leaves and obtaining biogas from plant raw materials of urban parks is considered. The calorific characteristics of the biogas obtained were quantified and analyzed. The chemical composition of the plant substrate formed as a result of mesophilic fermentation of plant biomass is investigated. The practical application of a plant substrate as a fertilizer has been studied by the example of germination of vegetable seeds. The prospects for further research to optimize the fermentation regime of plant mass during the processing of fallen leaves are analyzed. Obtaining biogas from the fallen leaves of urban parks and squares makes it possible to simultaneously solve energy, environmental, and social issues, both local and more general.*

Keywords: *biogas, anaerobic bacteria, mesophilic regime.*

Date of Submission: 03-11-2022 ***Date of Acceptance: 22-11-2022***

Introduction

The modern level of civilization development requires significant
the volume of energy consumption, including oil and gas, whose reserves are rapidly declining. Therefore, the search for alternative energy sources is an important and urgent task. In this regard, it is advisable to create installations capable of converting renewable (dispersed in nature) energy - water, wind, Sun - into energy localized in the necessary place and in such forms that would be convenient for its use. For example, solar energy is converted into electrical energy in semiconductor solar cells, in generators powered by Stirling engines, wind energy - in wind generators.

Plants are natural and effective accumulators and converters of solar energy. In the process of photosynthesis, plants convert inorganic substances scattered in the atmosphere (primarily CO2 and H2O) into organic,

capable of releasing heat during combustion. But another way of releasing the energy accumulated by plants is also possible – it is the production of biogas. Technically, it is more profitable and convenient to burn biogas than firewood, dead wood, etc.

According to the State Statistics Committee, 125.6 million tons of household waste appeared in the republic by the end of 2020. It is noted that the largest part of them was formed in Navoi - 48.2%, Tashkent - 34.6% and Jizzakh – 9.1% regions. Processing of such an amount of waste can only give biogas from 10 to 20 billion m3, or in terms of methane – from 8 to 12 billion. m3 per year. Currently, Uzbekistan's production in 2021 is more than 53.8 billion. m3 of natural gas. Using at least part of the waste potential will reduce the use of natural gas, solve a number of environmental problems and obtain high-quality fertilizers in addition.

The purpose of the work is to study the possibilities of utilization of plant raw materials of urban parks, the consequence of which would be the production of biogas and organic fertilizers.

The research results showed.

Methods

Biogas is formed during the decomposition of organic substances as a result of an anaerobic microbiological process - methane fermentation. Depending on the type of organic raw materials, the composition of biogas may vary, but the basis is methane (CH4) - the product of the vital activity of methane bacteria and carbon dioxide (CO2) - the product of the respiration of microorganisms [1]. In general, the composition of biogas includes methane, carbon dioxide, a small amount of hydrogen sulfide, ammonia, hydrogen and other gases.

The composition of biogas determines its physical properties (for example, the volumetric heat of combustion), and, accordingly, the possibilities of its practical use.

Various organic wastes are used as raw materials for industrial biogas production. Biogas plants can be installed as sewage treatment plants on farms, poultry farms, sugar and alcohol factories, meat processing plants, during wastewater treatment of megacities [2-4]. A biogas plant can replace a veterinary and sanitary plant, i.e. carrion can be disposed of in biogas instead of meat and bone meal production. Technologies have advanced so far that they make it possible to obtain biogas from almost any raw material of organic origin. For example, in Western Europe, more than half of all poultry farms are heated with biogas. Volvo and Scania produce buses powered by biogas.

For the formation of biogas from plant raw materials, it is necessary, first of all, to create comfortable anaerobic conditions for the vital activity of three types of bacteria. These bacteria are successors among themselves, i.e. the subsequent species feeds on the waste products of the previous species. Firstly, these are hydrolysis bacteria (they are responsible for the processes of destruction of biomass under the dissociating action of water and temperature), the second type is acid–forming bacteria (they allow obtaining organic acid molecules from hydrolyzed products) and, finally, methane-forming bacteria, which regulate the processes of consumption of organic acids and the formation of biogas [5].

In the process of biogas production, not only bacteria of the methanogen class are involved, but all three species.

Ecologically important (and not satisfactorily solved in Uzbekistan) is the problem of utilization of leaves fallen from trees in urban parks, weeds, etc. The natural processes of decomposition of

leaf biomass are slowed down (Fig. 1, a, b) and amount, depending on the humidity of the environment, for more than two years [4]. Utilization of plant biomass in garbage collectors requires significant costs, and the burning of such raw materials leads to atmospheric pollution and is prohibited by law. Therefore, in our opinion, the most expedient solution to the problem of utilization of plant biomass (fallen leaves, weeds, etc.) would be to obtain biogas.

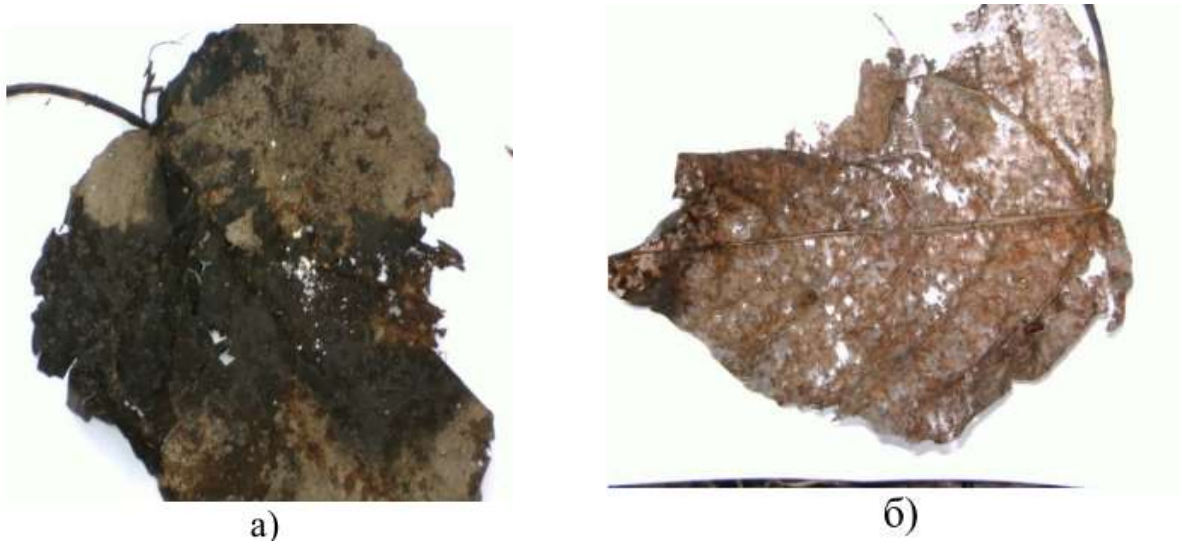

Figure 1 - Decomposition of leaves in natural conditions for six months in a wet (a) and dry environment (b)

In connection with the above, it was relevant to determine the conditions necessary for such a process of decomposition of fallen leaves, the products of which would be combustible gas and organic fertilizer.

It should be noted that animal raw materials for biogas production, for example, cattle manure, is a fairly homogeneous and sufficiently crushed mixture. Methane-producing bacteria are initially contained in the gastrointestinal tract of cattle. The essential advantages of plant raw materials are their availability (for example, fallen leaves in urban parks, weeds) and the cost-effectiveness of biogas production.

As plant raw materials in September–October 2012, fallen leaves were collected in the Dnieper Park of Kremenchuk. The vegetable mixture in equal proportions contained maple, poplar, ash, aspen leaves and about 10% ambrosia. The relevance of the disposal of ragweed and other allergenic weeds is increasing every year, because the number of people suffering from allergies is increasing every year. Therefore, one of the tasks set by us in the course of research is the possibility of not just recycling allergenic plant raw materials. To paraphrase Gaidai's movie hero: "Let what hinders us help us," i.e. - why not get biogas from weeds?

In order to disrupt the integrity of the wax coating on the leaves and increase the interaction area for bacteria, the raw materials were crushed to the size of small leaves (3-5 cm 2). The total mass of raw materials was about 5 kg.

Fallen leaves – the "children" of the oxygen atmosphere, as a rule, are washed by rains, therefore, unlike algae, they do not contain anaerobic bacteria on their surface. To populate the nutrient medium with anaerobic bacteria and optimize humidity, silty (non–flowing) water from

the Kremenchug reservoir in the volume of 3.5-4 dm3 was added to the plant mass. Wastewater can also be used for this purpose [4]. No catalysts were added.

Methane bacteria manifest their vital activity within the temperature range from 3-4 0 C to 70-90 0 C. If the temperature is higher, they begin to die, at subzero temperatures they survive, but cease their vital activity.

Since the metabolic activity and reproduction level of methane bacteria are lower than acid-forming ones, with an excess of acids (pH below 6.5), the activity of methane bacteria decreases.

On the other hand, an increase in the pH value of more than 8.0 (an excess of amino acids) also leads to a damping of the methane formation process. Usually the pH value is maintained at a constant level.

Also, for the active vital activity of organisms, it is necessary to maintain normal pressure, for example, to accumulate biogas in an elastic reservoir. The humidity of the feedstock should be 85-92% [2].

There are two main modes of rotting – mesophilic (at a temperature of 25-40 0C) and thermophilic (at a temperature above 40 0C) [2]. For our research, the most common – mesophilic mode was chosen. The moist vegetable mixture was placed in a glass container with a volume of 10 liters and placed in a dark place under a water gate blocking air access. For 9-10 weeks , the temperature of the vegetable mixture was maintained around the clock in the range of 28-32 0 C. The pH level of the resulting mixture was 6.5-7.0. The biogas released during the rotting process accumulated in a special rubber chamber. From the specified mass of the vegetable mixture (about 5 kg), about 9-10 dm3 of biogas was released during 1.5 months at normal atmospheric pressure.

The specific heat of combustion of the resulting biogas was determined experimentally using a reference heat receiver. This value is determined mainly by the methane content, since insignificant amounts of hydrogen and hydrogen sulfide practically do not affect this indicator. For the resulting biogas, the calorific value was 9.6 MJ/kg, or 2.3 kcal/l. For comparison: coke oven gas – 16 MJ/kg, natural gas - 35 MJ/kg [1, 4]. The calorific value of biogas containing 70% methane is 25.1 kJ/dm3, or 5.99 kcal/l [4]. It is possible that the optimization of the rotting regime will increase the percentage of methane, and, consequently, the caloric content of biogas.

It should be noted that the energy use of biogas in comparison with the combustion of natural gas, liquefied gas, oil and coal is neutral with respect to CO2, since the carbon dioxide released remains within the natural carbon cycle and is consumed by plants during the growing season.

Thus, the concentration of carbon dioxide in the atmosphere, compared with the use of solid fuels, does not increase. In addition, the energy obtained from biogas belongs to renewable, since it is produced from an organic renewable substrate.

The main directions of biogas use are:

1) power generation;

2) burning of biogas in boiler plants for heating water and supplying it to consumers;

3) preparation of biogas in accordance with the requirements of regulatory and technical documentation and its supply to the gas distribution networks of local natural gas consumers (mixing with natural gas);

4) cleaning, compression and filling with biogas of gas-cylinder cars, tractors and other types of transport;
5) obtaining nutritious biomass as fertilizer.

The choice of the direction of biogas use is determined on a case-by-case basis for each farm. To date, the issue of providing farms with electricity and burning biogas in water heaters is the most acute.

In the process of obtaining biogas from plant raw materials, in particular, from fallen leaves, a rotted mass is formed, which can and should be used as a high-calorie organic fertilizer. Previously performed scientific studies show that the resulting biomass does not contain weed seeds, helminth eggs and other pests. Depending on the composition of the feedstock, on the type of soil, as well as on the crop for which fertilizers are planned, the resulting plant substrate can be enriched with nitrogen, phosphorus, potassium raw materials. At the same time, the fertilizer consumption will be 1-5 tons per hectare, instead of 50-60 tons of untreated manure [4]. As a result, the quality of the fertilizers obtained increases the yield of the soil and reduces the cost of purchasing expensive mineral fertilizers. In some farms, it is more profitable to produce and sell the resulting fertilizer than meat or milk. It should also be noted the ecological quality of agricultural products grown with the use of such fertilizers. The chemical composition of the rotted plant biomass obtained by us was studied using a high-precision spectrometer with a continuous spectrum radiation source. The results of the analysis are shown in Table.1.

Table 1.

The content of some metals in the plant substrate

Chemical element	Concentration, mg/dm3
Aluminum	0,07
Barium	2,48
Vanadium	0,05
Iron	1,09
Potassium	1968,75
Cobalt	0
Silicon	81,25
Magnesium	393,75
Copper	0
Molybdenum	0
Sodium	1006,25
Nickel	0
Lead	0
Chrome	0

Zinc	0

An important feature of the obtained substrate is the absence of heavy metals in the composition, perhaps this is a consequence of the collection of raw materials not in the industrial zone of the city. For a more detailed analysis of the compliance of the content of heavy metals in raw materials, depending on the area of the city and generalized conclusions, further research is required.

The resulting substrate was used as a nutrient mixture for germination of vegetable seeds. Seeds (20 pieces each) of common vegetable crops were sown in a container with a soil mixture. For comparison, the same seeds were germinated in ordinary soil (the soil was taken in the city limits) without nutritional mixture and other additives.

All other things being equal, the germination of seeds in the presence of a nutrient mixture is 100%, in ordinary soil – 40-70%, the terms of growth and maturation also differ. For example, the seeds of cucumbers, watermelon and pumpkin sprouted 1-2 days earlier when the plant substrate was introduced into the soil. When transplanting seedlings into the open ground, the first sprouts turned out to be more resistant to hot, dry weather.

Conclusion

Biogas can be successfully obtained from plant raw materials of park tree species, weeds, in particular, from fallen leaves. In fact, it is an environmentally friendly fuel, similar in its characteristics to natural gas. The calorific characteristics of the biogas produced indicate the cost-effectiveness of its production. The remaining substrate can be used as an effective fertilizer.

The use of such raw materials makes it possible to simultaneously solve energy, environmental, and social issues, both local and more general.

- the production of biogas from fallen leaves contributes to the effective utilization of such raw materials and the improvement of the environmental situation.

Utilization of leaves by mesophilic fermentation with subsequent combustion of biogas reduces greenhouse gas emissions.

- with rising energy prices, the implementation of a project to extract biogas from fallen leaves will become an alternative to traditional energy facilities and will begin to make a profit in a few years.
- the development of biogas energy solves employment problems, contributes to the development of energy infrastructure.

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