INVESTIGATION PRODUCTION OF BIOGAS AND ELECTRICAL ENERGY FROM WASTE OF SUGAR INDUSTRY

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Abstract: Supplying and providing energy in the future is one of the major challenges for international energy organizations and countries having energy reservoirs. Nowadays, due to the increasing use of fossil fuels in the world, as well as their price and environmental impacts, the need and interest in replacing them with new and renewable energy sources has been increased. Anaerobic digestion is one of the attractive methods for producing biogas from organic materials. Biogas energy is also known as Green Energy because it is avaluable energy source in rural areas. Biogas provides a renewable energy source that is clean and easy to control. Becauseit requires lowmanpower, it can be an alternative for firewood or fossil fuels. One of the major sources for biological waste is the organic waste of food industry factories. In Iran, a large amount of these wastes belongs towaste of sugarindustries. In this research, the potential of biogas production by anaerobic digestion method and finally the amount of energy generated by these wasteswas estimatedduring one year. Firstly, the annual production of this industry in the country was estimated through field and library studies and interviews as well as referring to existing statistics. Then, by referring to one of the factories, the amount of waste was determined as a ratio of waste to production and finally the sampling was done. Thenthe requiredcharacteristics for anaerobic digestion were measured.Since the amount of biogas depends directly oninterestedvolatile solids, the amount of biogas production was estimated as 1641024 m^3, and therefore the annual electrical energy produced by this waste was estimated as12.13 GWh. The results showed that biogas is produced in large reservoirs called digester. There are many types of digester, but thesharedproperty is that they should workanaerobically or without oxygen. This amount of electrical energy is very significant and can provide a large amount of required energy in this industry.

Keywords: Renewable energies, Biogas, production of Electricity energy, Waste of Sugar industry, anaerobic digestion

I. INTRODUCTION

The energies of biochemical processes are used as a quantityto describe the state of a particle, object or system. The International Energy Agency (IEA) believes that by 2040 the world will use more fossil fuels such as coal and oil, and global energy consumption will increasesharplyand demand for global energy demand will increase in developing countries, especially Asia and China, which has recently become the world's highest energy consumer, previously owned by the United States, will have the largest share in world consumption growth over the next thirty years. One of the problemswith whichthe developed countries will be facedin the future isgreatcarbonemission in 2040 and this action causes new changes and pressures in geopolitics. Also, this change will lead to the advancement in energy-related technologies so thathuge losses will be experiencedby energy-producing countries in the energy market in the 2040 if they do not have access to these technologies. For example,Russia depends heavily on oil and gas revenues. Considering the increasing use of fossil fuels in the world, adapting methodsto reduce environmental impactsis necessary to predict environmental effects (positive or negative) imposed by a design, policy, plan, or project before deciding to realizeit. The assessment of formal impact may beeithercontrolled by the rules of implementation onthe public participationand the decision-making documentationsor may be in thejurisdiction area. Evaluating the impacts may suggest takingactions for adjusting effects to acceptable levels or reviewing new technology solutions. Also, regarding theprice and environmental impacts of fossil fuels, nowadays the need and interest in replacing them by new and renewable energy sources have been increased. These new energy sources are accessible, non-pollutant and practically inexhaustible. Suchsignificant features for new and renewable energy sources have made them as important resources for the future of developing countries. In Iran, new energy sources areespeciallyimportantdue to the increasing need for energy and limitations of fossil fuelsto keep the environment healthy, reduce air pollution and provide fuel for far villages. Biogas is one of these renewable energy technologies gained plenty of benefits [1].

Since in the present period the wastes(both solid and liquid ones) are increasing and it is possibletoproduce biogas from these materials, the construction of such power plants have been focuseddue to the ease of technology and the construction of biogas plants in manythe countries. Regarding the low cost of anaerobic system in comparison with other processes and ease of its technology, climatic conditions and types of waste in Iran, it seems that if priority is given to the anaerobic system, then biogas plants are to be constructed, they can reduce microbial and chemical contaminants and greenhouse gasesin addition to provide some part of the neededenergy, enriched fertilizers and irrigation water in the community [2].Removing unpleasant odor and harmful insects

from the suburbs aresome notable benefits for use of anaerobic digestion to control the waste. Due to the increasing amount of organic wastein Iran (about 15 million tons per day), works on controllingwaste and producingbiogasare inevitable. Unlike other renewable energies, biogas does not have a geographical constraint to produce energy and it does not require complex technology [3].This gas is completely odorless and smokeless when it is burning and it does not have any harmful effect on the environment. In addition, the dispersion of animal excretion and wastes of organic materials, which itself can be the center of the vermin conveying various diseases and the parasites causing harmful diseases are thus eliminated from the human environment.As a result of fermentation in the generators of biogas and their destruction, significant improvement can be seenin environmental health and the farms are protected against pests, thus the spread of diseases is effectively prevented and the safety of rural areas is increased. This method isthe most important method for cleaning ofenvironment in rural areas[4].

Biogas is a source of renewable energy that is obtained from biomaterial. Biomaterial includeseitherliving organisms or their remnants. The collection of gases produced from the decomposition and fermentation of animal or human and plant excrements resulting from the lack of oxygen and the activity of anaerobic bacteria, especially methane-producingones in a fermentation chamber are called biogas [5]. Generally, the average biogas constituents obtained from digesters include 40-75% methane, 25-40% carbon dioxide and small amounts of other gases [6]. Burning one cubic meter of biogas can generate 5500 to 6500 kilocalories of heat. One cubic meter of biogas is equaled to 0.4, 0.6 and 0.6 Kgof diesel, oil and coalfuels, respectively [7].

The ultimate and importantresult of a biochemical process is to achievehypotheses resulted from biochemistry. Anaerobic digestion is a multidimensional biochemical process that can convert almost all types of organic biodegradable materials torich biogas energy including methane and carbon dioxideunder anaerobic conditions [8]. Adapting an appropriate design and planning, the process of anaerobic digestion that has been used in nature for millions years can be managed to convert the wastes from being aprobleminto a capital [9]. Anaerobic method, in comparison with the aerobic process, requires less energy and less initial investment as well as produces less sludge. Production of biogas using an anaerobic digestion process is a goodalternative as a renewable energy[10].

All living organisms in the planet have biochemical constituents in their structures, and the task of biochemists is to examine and identify the structure of these materials and their roles in the lives of living beings. In a research, an anaerobicthermophile digestion (55 ° C)was performed onroots of sugar beet. In this experiment, a glass bottle with 5 liters capacity was used as an anaerobic digester. The digester was located in an incubator at 55 ° C inorder to provide thermophile conditions. The amounts of biogas and methane weredaily measured. The results showed that these wasteshave11.0% solids and 90.4%volatile solids, indicating a high potential for use in anaerobic digestion. The potential of biochemical methane from these wastes showed about 295 liters of methane in standard conditions per each Kg of volatile solids [11].

In previous years, living organisms lacked chemical elements in their bodies, and it was thought that only living organisms areable to make life molecules. In a research, the production of gas for cooking consumptions from wastes of sugar industry was evaluated. For this purpose, the properties of the filter mudproduced from the wastesof sugar factorieswere determined. These wastes contained a significant amount of organic materialsranging between 73% and 77%. After analyzing the components and confirming its appropriateness, a laboratory scale study was done. The results showed that the maximum amount of biogas from the filter mud can be produced as a feed ifthe concentration of solids ranges between 6% and 8%. Outside of this range, the production rate is decreased. It was shown that the average biogas of39.0 L per dayat the concentration of 8% is higher than other concentrations [12].

The process of anaerobic digestion is the analysis in the absence of oxygen whoseresult is the production of biogas and stabilized materials. The most tangible example of this process is in Landfill. In a research, biogas production was tested for some wastes including the filter mud of sugar factories. Solids and volatile solids of these wastes were measured. The samples were then added to the sewage sludge used as inoculum and were kept at 30 ° C during the experiment. Its biogas and methane were measured. The results showed that these wastes contained 7.208 g and 163.8 g solids and volatile solids per eachKg of waste, respectively equivalent to 78% of solids. From these wastes, 513.5 millilitersbiogas per each gram of volatile solids was obtained which us equal to 84 m^3per each ton of waste. This amount isa remarkable value in comparison with other previous studies. The percentage of methane in formedbiogas was 61.4% [13]. In another research, biogas production was evaluated using wastes of compressed sugarcanemud. Laboratory test was done in a anaerobicfloating container digester with a capacity of 1 m^3under a continuous process. Cow manure was used as an inoculum. Then, the primary feed containing compressed mud was fed in 2 wet and dry conditions

with equal 1:1waste towater ratio and the process was maintained at 30 to 35 °C under mesophilic conditions. The highest amount of biogas was 68$m^3$of dry compressed mud and the concentration of methane was 67% [14].

Excretionof plants and animals and other resources is used in the anaerobic digestion process to produce biogas. In a study, bio-methanation of by-products of sugar beet was studied by semi-continuous digestion as single digestion a co-digestion with cow manure. Firstly, the physicochemical properties of the wastes were determined. An anaerobic digestion test was then carried out in semi-continuous stainless steeldigesterwith 10 liters capacityunder continuous mixing. The digesterswere kept under mesospheric conditions (35 °C) by a hydrothermal circulation system[15]. The results of physicochemical analysis showed that the by-products of sugar beet contain 5.89% organic materials (volatile solids). Above organic material showed these wastes as a suitable substrate for biogas production. The results of the anaerobic digestion test showed that the highest methane production was252.71 ml of methane per each gram of volatile solids added during a 20-day hydraulic retain time, which formed 54.48% of obtained biogas. Also, the co-digestion of these wastes with cow manure reduced the hydraulic retention time to 15 days and improved the performance of digester and increasesthe production of biogas by 32%. [16].

Therefore, with regard to above subjects, the main goal of this research is to answer the following questions:

1. Investigating and measuring the annual waste of sugar industries
2. Identifying wastes of sugar industryand assessing and evaluating the desired characteristics of them for biogas production.
3. Ratingproductionpotential ofbiogas and energy from wastes of sugarindustry

II. THEORETICAL FUNDAMENTALS OF RESEARCH

2.1. Sugar

Cultivation of sugarcane in Iran, especially in Khuzestan, known as sugary place of Iran, was carried out, but for various reasons it is not clear that why sugarcane cultivation and sugar industry from cane sugar was destroyed in the Khuzestan province. After centuries of negligence, cultivation of sugarcane through grafting was begun experimentally in the Ahoudasht, Ahvaz, Hamidyeh and other susceptible regions of Khuzestan during the 1937 to 1941. The cultivated area reached to 300 hectares in 1941. Finally, in 1959, the construction of the Haft Tapeh cane plant with a capacity of 10,000 tons of cane sugar was started and the factory started its first operation period in December of 1961 with under cultivation area of 2400 hectares. In 1975, the second cane sugar factory with a capacity of 20,000 tons could be increased up to 30,000 tons was constructed in Karoun Cultivation and Industry in northern region of Shoushtar [7].

2.2. Cycle of energy production

There are some cases where both physical and chemical changes occur on a phenomenon sequentially. For example, by heating a single piece of sugar in anexperiment tube, at first the sugar melts, which is a physical phenomenon. It then turns brown, indicating the beginning of the conversion of sugar into carbon which is a chemical phenomenon. Then, a couple of water vapor hits the top of the tube, indicating the decomposition of sugar following the previous chemical phenomenon. Afterward, water droplets appear on the wall of the test tube, which indicates the condensation of water vapor as a physical phenomenon. At the end, the black, flavorless and insoluble in water substance (unlike initial glucose)remains which is coal and, due to change in color, taste and its solubility in water, this case indicates a chemical phenomenon. Any kind of bond between the different atomic constituting molecules of an object has a kind of chemical energy whose amount depends on the type of atoms and how they are placed in the molecule. In a chemical reaction, in fact, the binding of atoms to each other changes in reactions, and as a result, the chemical energy of the reaction products changesrespect to the chemical energy of the reactants [13].

2.3.Amount of biogas production in sugar factories

In most of the world's sugar cane factories, steam furnaces as the main sources of electromotive force for power plants and factory consumptions are designed to use a variety of fuels such as bagasse, liquid and gasfuels. The factories constructed in Iran are also designed in this way. Of course, it has been tried to use oil as fuel, but bagasse is utilized whenever there is a problem in using oil for some reasons. The bagasse heat output is 2000 Kcal per eachKg of bagasse [6]. As bagasse can be used as a heat source for producing steam and electricity at the factory site, large quantities of bagasse produced in the sugar cane process allow selling the surplus produced electricity. For a cane factory, it is possible to produce 60 kilowatts electricity through processing each ton of sugar cane. In some cases, this surplus electricity can make a significant contribution to meet the national electricity needs, especially in small countries with a strong cane sugar industry [5].**Production of biogas / methane:** Anaerobic fermentation of bacteria in a reservoir (on cellulose-rich materials) produces biogas with methane to carbon dioxide ratio of 35 to 26. Theoretically, 1 Kg of cellulose can produce 450 liters of methane. **Producer gas:** This gas is obtained by burning solid

fuel in air and steam (in the furnace) to create a mixture of burnt and unburned gases. Thus, this action done on bagasse leads to produce gas with a combination of carbon dioxide (11%), carbon monoxide (17%), methane (6%), hydrogen (6%) and nitrogen (60%), and it has a thermal value of 8760Kj / Kg. Use of this gas as a fuel for gas engines is a new and high-tech technology [10].

III. RESEARCH BACKGROUND

In his research (2010), Baloh concluded that using pinch analysis, the consumption of steam can be reduced up to 30% by converting the common 4-section evaporative systems to 5-section ones in sugar factories by which energy can be generated. In new 5-section system, required vapor for cooking was provided through 3rd section and outlet vapor was used to heat the raw syrup through the last section instead of entering into the barometric condenser. For using this system, it is necessary that Robert type evaporators be replaced with a variety of thin layers. Using this method along with utilizing energy engineering issues could reduce energy consumption in sugar beet plants by 30%.
In 1993, Christodoulou modified the heat exchanger network of Larissa 7200 ton factory using a pinch analysis, which eventually led to a reduction in the amount of fuel compared to beet consumption up to 35% and production of energy production from beet.

IV. MATERIALS AND METHODS

Theingredients of organic materials include coarse molecules, and the potential of biogas energy is determined in two stages:
1. Determining the amount of relatedwaste: By referring to existing statistics, relevant sites and interviewing with experts
2. Determining the potential of biogas forestimated wastes: Based on valid scientific sources and previous experiments.

Many researchershave been working in the field of biogas energy. Therefore, regarding the ratio of wastes in this industry it was realizedthrough visiting and interviewing withexperts of sugar industry factories that ratio of wastes in various parts of this industry is different so thatthisamount is 5%for the production of sugar from sugar beetand1% for other by-products. In most of the factories producing sugar products, steam furnaces are considered as the main sources of electromotive force for power plants and factory consumptions. In this research, the wastes were prepared from the Sugar Research Center. Samples were taken from wastes of available products. The samplewas transferred to the laboratory to measure the required properties. The most important factors affecting the production of biogas are: heat, acidity, carbon-to-nitrogen ratio and volatile solids (vs)content. Carbon-to-nitrogen ratio andwhich depend on the factors mentioned in the ratio of carbon to nitrogen and volatile solids content dependdirectly on the type of considered material. Therefore, the characteristics of the wasteswere determinedin the laboratory. The required properties for estimating the potential of biogas production were determined by standard methods mentioned in Iran Standard & Industrial Research Organization No. 13320. These characteristics include moisture content, solids content, volatile solids content, carbon content and nitrogen content (Table 1). Calculating the amount of biogas andequivalent energy basedon the characteristics of the biogas production amount from the unit weight of the waste varies depending on the different conditions, but usually it is obtained from 0.4 to 0.6 cubic meters 3 per eachKg of volatile solids. Also, the energy in the biogas is estimated to be 6 to 10 KWh per each cubic meter of biogas(depending on its methane content).

RESULTS AND DISCUSSION

The biogas consists of methane and carbon dioxide, but it may also contain small amounts of hydrogen sulfide, water vapor and Siloxane (silicon oxide). As already mentioned, the amount of waste in various sectors of the industry is different. The required properties for estimating the potential of biogas production from the desired wastes are presented in Table 1. As it can be seen in Table 1, most wastes of the sugar industry contain volatile solids with more than 90%volatilityindicating the high potential of these wastes for the production of biogas. The best ratio of carbon to nitrogen value for anaerobic digestion is20-30 to 1 andvery high or very low ratios disturb anaerobic digestion process.This problem can be solved by c digestion and optimization of this ratio, which it not only does not reduce the production of biogas but also improves both quantity and quality (increasing the percentage of methane in the biogas).
According to Table 1, for anaerobic digestion, these wastes have optimum carbon-to-nitrogen ratios in addition to having high volatile solids, which can be a good option for biogas and energy production.

Table 1: Physicochemical Properties for Wastes of Sugar Industries

Food group	Carbon to nitrogen ratio (%)	Nitrogen content(%)	Carbon content (%)	Volatile solids (%)	Total solids (%)	Moisture content (%)
Sugar Industry	25.32	1.88	46.89	23.6	26	81

According to the average values for characteristics of interested waste and the average amount of biogas for volatile solidswhich is considered as 0.5 m^3 / kg of volatile solids, the annual production potential of the biogas from the wasteis estimated in accordance with Table 2. As it can be seen, the annual amount of biogas through anaerobic digestion of wastes of sugarindustry is estimated as 1641024 m^3 which is a significant value.

Table 2: The amount of wastes andannual biogas produced from wastes of sugar industries

Type of plant	production (tons per year)	Waste amount (tons per year)	Average volatile solids (%)	Average solids (%)	Biogasamount (m^3 per year)	Biogasamount (m^3 per Kg)
Sugar Industry	198000	18700	98.21	26	1892364	0.9

* Solidsare a percentage of the wet sample and volatile solids are a percentage of solids.

Also, with regard to the biogas energy content mentioned in previous section, if its average is 8 kWh per cubic meters of biogas, this biogas is equal to 13.12 GWh of energy per year, which can provide a huge part energy demand for food industries. In addition, this energy is completely clean and renewable; it can be used as a suitable solution for managing industrial waste problems and preventing environmental pollution in addition to leading a sustainable economic development.

DISCUSSION AND CONCLUSION

Biogas is a process that involves breaking microorganisms and bacteria in the absence of oxygen. Biogas is a renewable energy source like solar energy and wind energy. Biogas can be produced from biomass or biologic waste, thus it is a environment- friendly process. In this research, the potential of producing biogasand energy by the anaerobic digestion of sugar industry waste is estimated. it was observed that a significant amount of electrical energy can be generated from this clean fuel. Considering finishing of fossil fuels, their environmental and greenhouseeffects and the omittingenergy subsidies, better policy and support should be provided for this new source. Also different industries can be studied. In addition, more studies and researches should be done in order to optimize the production of biogas and to achieve its maximum value and simultaneously to increase the quality of produced biogas, for example, by co-digestion.

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