IMPLEMENTATION OF ANAEROBIC PROCESS ON WASTEWATER FROM TAPIOCA STARCH INDUSTRIES

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ABSTRACT

The objective of this research is to study the effect of tapioca starch wastewater industries as substrate on an anaerobic fixed bed digester to the biogas production and to study the performance of 2.25 m^3 fixed bed digester. The research was conducted from February-November 2000 in Situraja, Sumedang, West-Java the benefit of this research is to obtain environmentally sound technologiest in the tapioca starch production-utilizing cassava roots as raw material and to supply additional energy within tapioca starch industries.

Method used in this research is the utilization of a fixed bed polyethylene bioreactor of 2.25 m^3 capacity. Support materials/media used was PVC pipe with the dimension of 65.5 mm length, 75 mm diameter, 1.5 mm wall thickness, and have surface area per volume/specific surface area of 45.32 m^2/m^3 with void volume of 93.5%. The inoculum utilized was filtered cow dung. The performance anaerobic process was done by Chemical Oxygen Demand (COD) controlling, biogas production measurement and methane content measurement. Chemical analyses was done in terms of pH, COD and biological analyses was done in terms of Biochemical Oxygen Demand (BOD).

The research results showed that the value of organic substance in the influent was in average of 10,062 ppm and 5,649 ppm in terms of COD and BOD respectively. Maximum organic loading rate applied was 7.8 kg COD/m^3 day. The efficiency degradation reached in average of 76% and 95.8% in terms of COD and BOD respectively. Methane content in the biogas was in the range of 53.5% to 71%. The average biogas productivity was 1.2 m^3 /m^3 of wastewater. Significantly increasing of pH value has been proven from around 4 in the influent and 7.04 to 7.13 in the effluent.

INTRODUCTION

The research was conducted in a private owned company that produces tapioca starch. The factory is located in Situraja, Sumedang, West-Java about 65 km from Bandung and it was established in 1987. Almost of the employees are daily workers and incidental workers. For that, the numbers are always different from day–to day. The working time is not fixed. It depends on the raw material (cassava) stock. The largest numbers of workers are concentrated in the drying process. They have responsibility start from collecting the starch in the sedimentation basin to the finished dried tapioca starch. Drying process is extremely on the sun dependent. In the rainy season, or when the sun is not shine, the wet tapioca is stored in the concrete basin and it should be flooded with water as an effort to preserve the tapioca. Even though it can be preserve for two months, as the result, the quality of the starch will decrease.

Activities of the factory produce liquid, solid, and gas wastes. Liquid waste is generated from extraction of cassava pulp. Solid waste is produced from peeling of cassava and extraction process of cassava pulp as well. While gas waste is generated from the biodegradation of organic material by uncontrolled anaerobic process. In this factory, the solid waste is mostly made use either for food additive or feedstock. Therefore, the liquid waste is the most important to be treated before discharging to the river.

Wastewater from tapioca starch factories released directly into the river before proper treatment. Consequently, it has been a source of pollution and has caused environmental problems to the nearby rural population. Anaerobic digestion of the wastewater then not only results in a production of a useful form of energy [1] but also deals with the problem of environmental pollution caused by the tapioca starch processing plants.

This paper contains result of an experiment biologically upon liquid waste by using anaerobic process. The experiment will identify the benefits of the treatment of liquid waste in order to compensate the environmental and the economic constraints and finally win – win position between economic and environment hopefully can be fulfilled.

PROCESS PRODUCTION OF CASSAVA STARCH

In the tapioca industries, the process production can be described as follows:

1. **Raw Material Preparation**

   Cassava root is bought from the farmer either from surrounding the factory or sometimes from central Java (approximately 350 km distances). The price of cassava roots is Rp. 250.- pr kg. This factory is located nearby the community; therefore, the workers are relatively easy to be employed. After weighing, the workers, usually women, peel the cassava roots. Recently, the peel is made use by people surrounding the factory for feeding of sheep.

2. **Raw Material Transportation**

   After peeling, by their own trucks, the peeled cassava roots then transported to the factory for subsequent processes.

3. **Washing**

   Washing of peeled cassava roots is done in a rotating drum like. The rotating drum is halving submerged in a basin, which contain wash water. The water flow continually and it discharges directly to the river nearby. The rotating drum equipped with screw mechanism to draw up the cassava root to the end part of the drum. Then simple bucket elevator transports the cassava roots in to the concrete basin.

4. **Grinding**

Manually, cassava roots are pushed to the grinder. The grinder is rotary type. Grinding process result cassava pulp, which should be separated into tapioca starch and fibrous materials.

5. **Separation**

Separation of cassava pulp need fine screen and water. The screen is 'vibrated' by action of eccentric rotation, while water is used to dilute the cassava pulp to make the separation process easier. Fibrous material will retained on the fine screen, while mixed water and tapioca starch will pass the screen and it flows to the sedimentation basin. The fibrous material flows to the basin, which is specially designed to separate water, contain in the fibrous material. The basin equipped with 'screen' made of bamboo. In this basin, the de-watering process is occurred. The water then directly discharges to the river, and the fiber is harvested and sold.

6. **Sedimentation**

The sedimentation basin in this factory is very long. It is more than 300 m length. The basin is made of concrete and glass laminated. The glass laminated purpose to maintain the cleanliness of product, especially in the harvesting process. The tapioca starch will precipitate, and the wastewater will directly discharge in to the river.

7. Harvesting

Harvesting of tapioca starch is done manually using shovels. The form of this wet tapioca starch is clump. Therefore, to reduce the size, they utilize size reductor driven by fuel-engine. The result is finer tapioca, which is ready to be dried.

8. Drying

Drying process is done by put the starch in winnowing tray (made of matted bamboo). Every tray has about 1.5 – 2 kg starch. The trays then are laid on the bamboo racks. The drying is totally depends on the sun. Usually the drying period is approximately 2 – 3 days.

9. Fine grinding

After drying process, the starch is then milled. The grinder is hammer mill typed.

10. Packaging

Finely, the tapioca starch is packaged in 50 kg - plastic bag and sold. The starch is sold in the range of Rp. 1,600.- to Rp. 1,700.- per kg. The yield of the product in between 20% - 25% based on the raw material.

UTILITIES AND EXISTING WASTES TREATMENT FACILITIES

Utilities in the factory include water system preparation, electricity, engine driver, and piping system. No waste treatment facilities are available in the factory.

Water System Preparation

The factory has simple water treatment for process water and washing purposes. Water source is taken from a water canal passing by the factory area. The factory has build a basin made of concrete, which has the dimension of approximately (20 x 15) m^2 with the average depth of 4 m. The basin is then separated into 12 sections by concrete partition. The factory does not built primary sedimentation basin. The first section basin receive the water from the small canal nearby by mean of gravitation. In this basin, there is alum in the PVC pipe, which has diameter of 4 inches (see Fig. 1. for the coagulation dosages). Coagulation and flocculation occur in first, second and third basins. Between section basin, in the partition, there are gates like, which are provided with palm fiber from the sugar palm as filter media. Based on this simple water preparation process, the process water and washing purposes in the factory can be fulfilled.

Electricity

The electricity need is come from public electricity grid. The needs of electricity mostly just only for lighting. Only minor electricity need for pumping the water for the elevation cause gravitational water flowing.

Engine Driver

The factory utilizes truck engines for driving all of the moving part. By utilizing axes, bearings, pulleys, and belts; the washing drum, bucket elevator, grinder, vibrating screen and all of the moving parts can be driven. This is an intelligent way of thinking to run such kind of business.

Piping System

Piping system can be found mainly in the process water and sanitation purposes. Canals are also available in the processing section. The pipes utilized are made of either iron or PVC.

Waste Treatment Facilities

No waste treatment facilities are available in this factory. All of facilities built are mainly for the efficiency of process production. Wastewater generated simply is directly discharge to the river. Local government seems to be 'reluctant' to avoid or to ban such activities. Even though wastewater generated from this factory can be reach approximately 200 m^3 per day. For one ton cassava roots need about 7 m^3 of water for its processing. For the owner point of view, building of waste treatment facilities seems to be suffering a financial loss. Just only through the law enforcement, discharging of such wastewater could be taken into account.

ANAEROBIC TREATMENT OF ORGANIC WASTEWATER

The pilot plant installed in the tapioca industry was fixed bed digester with cutted PVC pipe as packing media. Anaerobic fixed bed reactor establishes growth of the anaerobic organisms on a media. The reactor may be operated up-flow or down-flow. The packing media, while retaining biological solids, also provides a mechanism for separating the solids and the gas produced in the digestion process. In the fixed bed digester, characteristics of packing media become very important in its choosing. The characteristics influence the effectiveness of packing media. Factors influence the effectiveness of packing media include [2]:

1. **Size and Shape**

   Size and shape of a packing media influences the behavior of either mixing or flow of fluid in the digester. Therefore, bio-film formation at the surface of media, biological transfer and accumulation of suspended solid, substrate distribution, and organic substances degradation level in the digester will be influenced. Vertical installation of packing media tends to cause the transfer of suspended solid to become easier. Therefore, this system is suitable for treating wastewater with relatively high in suspended solid concentration. On the contrary, randomly installed packing media in the digester tends to block suspended solid transfer. Consequently, this kind of digester is suitable for treating low concentration suspended solid of wastewater.

2. **Surface Area and Volume Ratio**

   This ratio influences density of microorganisms attached on the surface of packing media per volume unit digester. The surface area is only to have important role when the density of microorganisms attached on the surface of media higher than microorganisms detached from the media and its laid down in between media. Consequently, performance of down flow reactor depends on the ratio of surface area and its volume. This is because of releasing unattached microorganisms together with the effluent. Conversely, performance of up-flow digester is greatly not affected by this ratio.

3. **Porosity**

   In high packing media porosity, the substrate velocity in the porous will lower. Therefore, bio-film formation can be occurred easily. Another advantage is economizing the use of reactor volume. Packing media made of clay occupies digester volume between 30% and 60%, while plastic media occupies only about 5% of digester volume. Therefore, by using plastic media and with specified wastewater volume, reactor volume can be reduced significantly, because volume digester is calculated in effective volume.

4. **Surface Roughness**

   Surface roughness of packing media has very important role in the start up of digester. Packing media with smooth surface will face difficulty in starting up procedures. This is because of attachment difficulties of microorganisms on the media surface.

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Materials and Experimental Techniques

Experiment was conducted in the area of the factory. Anaerobic process applied was fixed bed digester. The experiments were performed continuously. Flow diagram of anaerobic process can be seen in figure 2. Tapioca wastewater, the most pollutant substances generated from extraction of tapioca starch from cassava pulp, was utilized as substrate. Prior to be fed into the anaerobic digester, substrate should be pumped from the final sedimentation basin to the intermediate tank. Then from this tank, the substrate is further pumped to the substrate tank. This was done because the distance between final sedimentation basin and location of the mobile unit was about 300 m. Without any dilution, the substrate directly was poured into the storage tank. By using feeding pump, the substrate was entered into the anaerobic digester. Feeding pump worked depend on the timer regulation located in the control box. Feeding pump worked intermittently to feed the reactor with certain amount of feeding. The digester was provided with circulation system to dilute the feeding. As feeding pump, a timer also regulates the circulation pump. With the result that the concentration of organic substances in the bottom part of the digester was not too high and therefore, it maintained homogeneity inside the digester. This homogeneity is extremely important in order to avoid the accumulation of acid forming in the bottom part of the digester or at the port where the substrate is pumped in. Biogas produced then was measured by gas flow meter for measuring its production. Measurement of its composition by knowing the carbon dioxide content (measured in % volume) is done by sampling in a plastic bag and measured it by absorption method.

The specification of anaerobic digester can be seen in table 1. The anaerobic digester utilized regular storage tank made from polyethylene and widely available in common market. However, the most important properties should be fulfilled, namely: acid resistant and strong enough to hold the certain volume of substrate.

Method of Analysis

1. *Biogas production measurement.*

   Biogas production was measured by a gasflowmeter. It reads directly the numbers in liter of sum gas produced every day. It should be noted that the read of the numbers is performed daily at the same time in order to know the exact daily gas production. The gas production was recorded as the numbers showed without any correction factors, for example correction factor for temperature and pressure. The gasflowmeter utilized was wet type.

2. *Methane content measurement*

   Methane content was measured by absorption of carbon dioxide with 10% concentration of KOH [3]. The assumption by using this method was that biogas mainly constituted of methane and carbon dioxide gas, where the other gases produced during anaerobic process were neglected. The equipment was filled by certain amount of KOH. Then biogas was pumped into the apparatus, mixing was necessary by shaking the equipment. Afterwards, surface of KOH was clearly to determine the percentage of carbon dioxide, it reads in percent volume. When KOH has saturated, it should be changed with the fresh one.

3. *Biological Oxygen Demand (BOD).*

   The BOD_5 analysis required the measurement of dissolved oxygen of sample before and after incubation for 5 days at 20 ^{o}C and is calculated from the difference between the two measurements [3].

4. *Chemical Oxygen Demand (COD).*

   The test measured the amount of oxygen required for chemical oxidation of organic matter in the sample to carbon dioxide and water. The apparatus used in the dichromate closed reflux method consisted of closed flasks and heated in an oven [3]. Most types of organic matter were destroyed in this boiling mixture of chromic and sulfuric acid.

5. *pH.*

   The term pH is used to express the intensity of an acid or alkaline solution. Measurement of hydrogen ion concentration is most frequently accomplished by using a meter that reads directly in pH units.

RESULTS AND DISCUSSION

Daily biogas production will be elaborated. The digester performance will be evaluated into 13 steps based on changing substrate filled into the digester. The stepping of filling substrate did not always increasing step; sometimes the feeding should be decrease because of degradation process disruption in anaerobic digester. This was identified from the gas production or methane content (this is the quickest response in carrying out the anaerobic digester operation). The 13 step then, in this report called feeding procedure.

Figure 3. shows the daily biogas production from the anaerobic process. Biogas measurement was conducted from the day when the inoculum was filled into the digester.

The cow dung was treated before it was filled to the digester. The pre-treated cow dung was about 200 liter, it included straw and other impurities such as stones, grass and dry cow dung. The impurities were about 10%. Hence, the inoculum to be filled was 180 liter. This 180-liter then was diluted and screened. Again about 5% of coarse material were rejected in order to avoid the blockage of either the support materials or in the piping system within the anaerobic digester. Afterwards, the digester was full-filled with canal water, which is flowing nearby the pilot plant. The circulation pump was then intermittently operated with the debit of 160 liter per day.

During start-up time, no substrate filled in to the digester. The maximum biogas production was at 30^{th} day. It reached 204 liter. The subsequent days, the biogas production was decrease significantly. It meant that the digester was starving of organic materials to be degraded. It was the time for first feeding.

During first feeding, the digester was fed 53 liter per day of substrate with the average COD and BOD concentration of 11,560 and 6,480 mg/l respectively.

At the second feeding, the digester was fed 106.2 liter per day. Average influent concentration of COD and BOD were 10,062 and 5,649 mg/l respectively. The biogas production was shown quite constant, namely in the range of 500 liter per day.

During third feeding, the digester was fed daily in average amount of 159.3 liter. Biogas productions tend to be increased until the day of 147. The increasing of biogas production identified that the digester can cope with higher organic loading rate. Average COD and BOD concentrations were 7,913 and 5,385 mg/l respectively.

During 4^{th} feeding, the basic process was disrupted by lacking of substrate because no fresh wastewater found. No cassava was delivered at that time. The cassava roots were not mature yet to be harvested. However, using rest of wastewater available in the final basin of the factory still could operate the pilot plant. The weakness of utilizing non-fresh wastewater as substrate can be identified the lower of organic content and higher of its acidity. Average COD and BOD concentration were 7,167 and 3,508 mg/l respectively. Therefore, the performance of the digester was not satisfactory. Other events were also should be taken into serious attention. Leakage at upper parts of the digester was experienced. After repairing the leakage, the biogas production was sharply increased. However, performance of the digester was seemly decrease in treating such wastewater. Therefore, at 5^{th} feeding, the inlet was decreased in half.

During 8^{th} feeding, inlet applied was 165.94 liter per day of wastewater. Decreasing COD concentration in the feeding caused the decreasing of biogas production. Organic material concentration in term of COD and BOD were 9,000 and 5,802 mg/l respectively.

During 9^{th} feeding, the biogas production tended to decrease slightly. However, the methane content was high, namely 70%. Therefore, it has been identified that the digester was in well performed. The average feeding was 278.75 liter per day with the average concentration of 8,333 and 5,013 mg/l for COD and BOD respectively.

At 10^{th} feeding, the digester was boosted with the average amount of substrate of 398.25 liter per day. The average concentration of COD and BOD were 7,750 and 4,614 mg/l respectively. The response of the digester was quite well. The maximum biogas production reached 1,609 liter with average methane content of 64%.

During 11^{th} feeding, the digester performed well with the average feeding of 597.5 liter per day. The average organic substances were 8,288 and 5,313 mg/l for COD and BOD respectively. The maximum biogas production was 2,066 liter with 61.5% methane content.

The maximum biogas production at 12^{th} feeding was 2,076 liter with the average methane concentration of 57%. Average volumetric feeding was 915.98 liter per day. The average concentration of COD and BOD were 11,100 and 5,113 mg/l respectively. It seems that the digester has experienced over loading. However, as a matter of fact that this observation can be little bit prolongs to reach shorter hydraulic retention time.

Figure 4. shows the relation between debit and biogas production. The digester responded very well. A matter of fact, that feeding could be increased. The increasing of feeding (debit) proofs this, the biogas production is still active. Therefore, the digester could bear heavier organic loading. The maximum organic loading rate (OLR) applied was 7.821 kgCOD/m^3.d. at the 13^{th} feeding procedure. The digester was not in maximum loading yet, however, this point was nearly to be reached. While figure 5. shows the correlation between OLR and efficiency of the digester performance in term of COD parameter. When OLR was increased, as a result the efficiency of organic substance degradation was decrease. This phenomenon is normal and it is also to identify that the digester capacity has limitation. With the applied OLR, the average efficiency was more than 76%.

Figure 6. identifies the correlation between OLR, pH inlet substrate, and pH outlet from anaerobic digester. The anaerobic process performed well in buffer capacity, even though the inlet pH was relatively low. Inlet pH was relatively constant around 4. Increasing

in pH outlet to become more than 7 proved that the anaerobic process performed well. Very slightly of decreasing pH was occurred when the digester was loaded with the maximum OLR (COD) within this observation. The decreasing of pH was just from 7.13 to 7.04. This identifies that the digester performance still can be better by subsequent increasing of OLR.

The effective volume of the anaerobic digester was 1,300 liter. In figure 7., the biogas production was exceed the digester volume at 12th and 13th feeding procedures. In these feeding procedures, the biogas productions were 1.265 and 1.282 of effective digester volume respectively.

CONCLUSION

Biological treatment system is the best way to overcome the difficulties in treating organic wastewater, especially from the tapioca starch industries. This treatment system is the most suitable in the era of technology application. Benefit from the process can be obtained by utilizing biogas production to be fuel, which can be used to dry the wet tapioca starch. Therefore, win-win situation can be obtained by application of this system. Win-win situation is between environmental and economical consideration.

Fixed bed digester for anaerobic process is the best practical approach to be applied in treating tapioca starch wastewater. With high efficiency of organic biodegradability; relatively low cost in operation for no prior treatment of the substrate either pH, temperature, concentration condition or nutrient addition; relatively low cost in maintenance; and valuable fuel as side product; makes the anaerobic process to be the favorite technique to treat and make use this kind of wastewater, not as waste, but as spent resources.

This research also result methods of start up procedures, operation manual, and trouble shooting. Hence, design of full-scale anaerobic treatment in tapioca starch industries can be performed based on the data collected through this experiment. Potential side product, such as biogas has also been recorded in order to prove that the biological-anaerobically treatment of tapioca starch wastewater gives valuable contribution to the tapioca starch industries in Indonesia as one of the alternative energy source.

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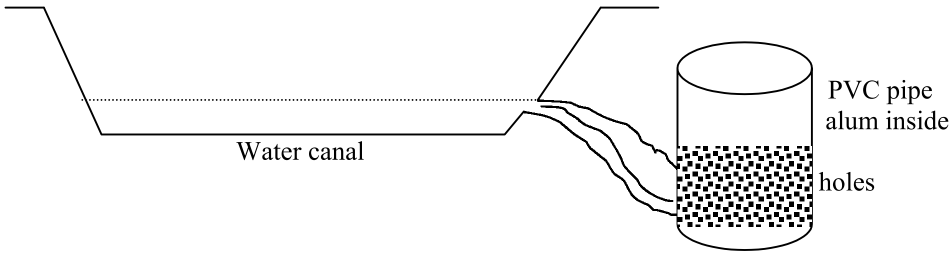
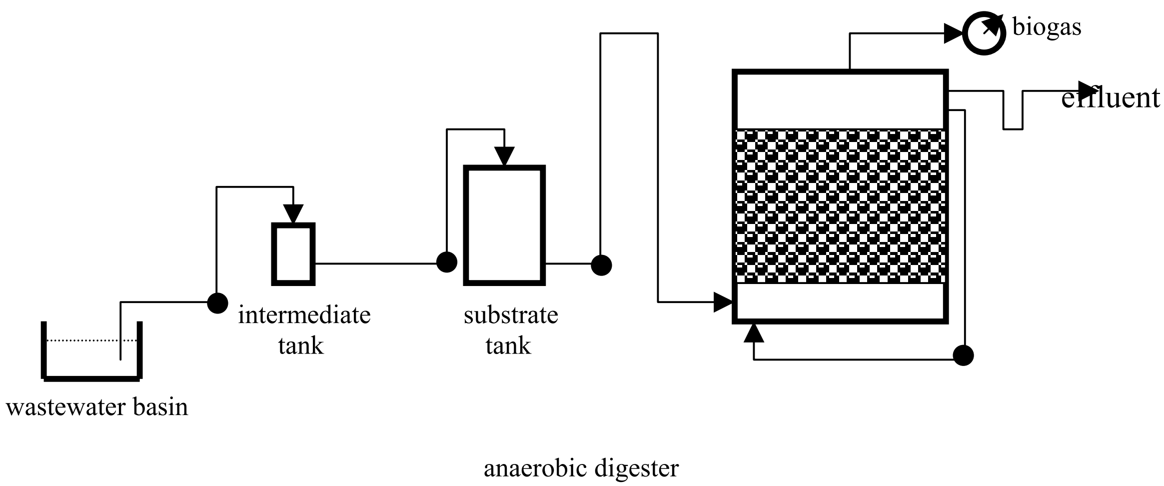


Fig. 1. Alum dosage and “rapid mixing” system.



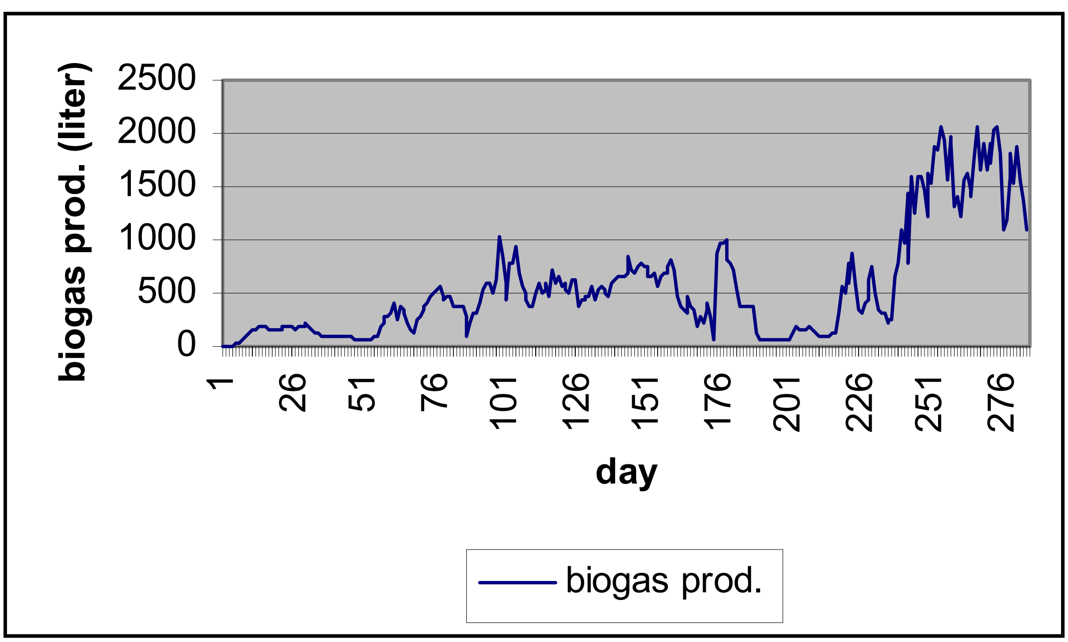
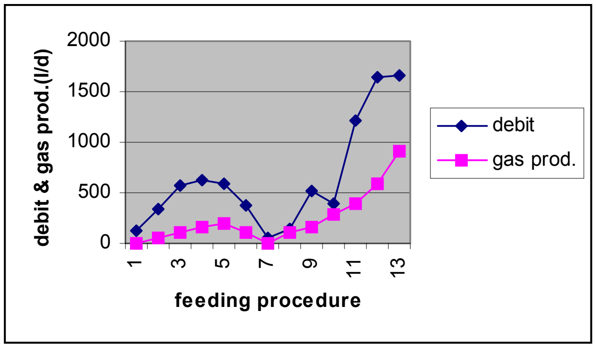


Fig. 2. Flow diagram of anaerobic fixed bed pilot plant.

Fig. 3. Daily biogas production.



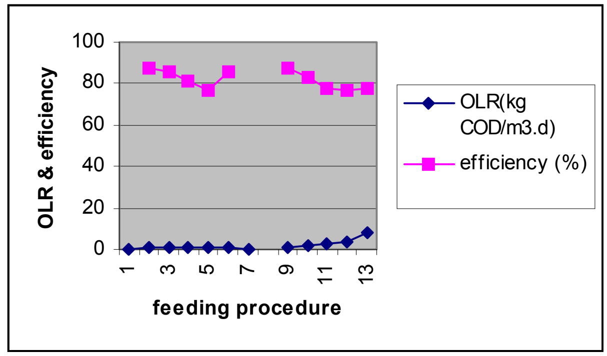


Fig. 4. Debit and biogas production.

Fig. 5. OLR (COD) and efficiency.

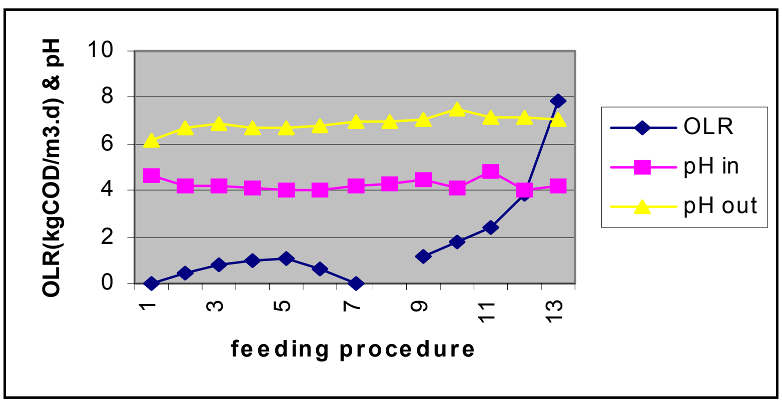


Fig. 6. OLR (COD) and pH.

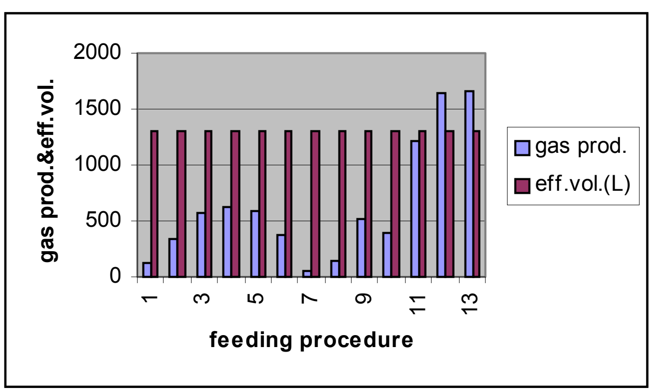
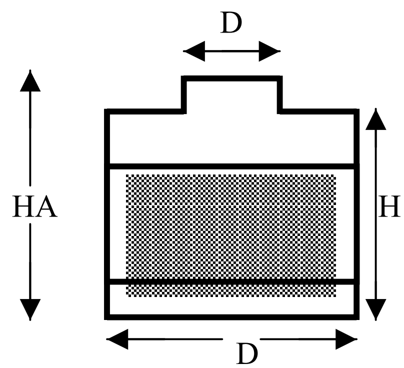


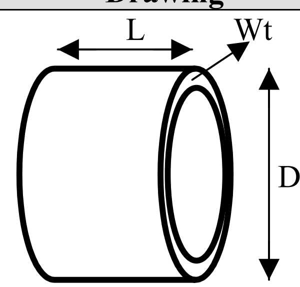
Fig. 7. Biogas production and effective volume.

Table 1. Specification of Anaerobic Digester.

Item	Dimension	Drawing
Material	Polyethylene	
Empty volume	2250 liter	
Lower diameter (D)	1440 mm	
Height (H)	1480 mm	
Total height (HA)	1580 mm	
Upper diameter (d)	600 mm	
Wall thickness	10 –12 mm	
Filled volume*)	1986 liter	
Effective volume**)	1300 liter	
Packing media***)	3000 pcs.	

*) Total volume of liquid, sludge (inoculum), and packing media.
**) Liquid volume.
***) Specification can be seen in table 2.

Table 2. Specification of Packing Media.

Item	Dimension	Drawing
Material	PVC	
Diameter (D)	75.00 mm	
Length (L)	65.50 mm	
Wall thickness (Wt)	1.50 mm	
Void volume (porosity)	93.50 %	
Surface area per volume	45.32 m^2/m^3	