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Production of biogas by using anaerobic sludge digestion of sago waste

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Abstract
The current work focuses on the generating bio-gas from sago waste produced by sago production plant in Attayampati using anaerobic digestion process. Attempts have been made to optimize various parameters in order to determine the most favorable recipe for maximum biogas production from the digested sago waste. The biogas yields have been determined using batch anaerobic thermophilic digestion tests for a period of 90 days. Characteristic oscillation was observed in the rate of methane production, which may be due to the presence of methylotroph population in the activated sludge, which uses methane as a carbon source for their growth. The total biogas generated in the system over the experimental period was the sum of methane and carbon dioxide. Biogas produced from the decomposition of sago waste was a mixture of 76% methane and 24% carbon dioxide.

Keywords: methylotroph, biogas, sago waste, methane, activated sludge

Introduction
General
Biogas refers to a gas made from anaerobic digestion of biodegradable waste. Methane is a clean energy one of the constituent of biogas which has a great potential to be an alternative fuel. Abundant biomass from various sago production plant could be a source for Methane production where combination of waste treatment and energy production would be an advantage. Tapioca Sago is generally Known as SAGO (SABUDANA in Hindi or JAVVARISHI in Tamil) in India. Sago is a produce, prepared from the milk of Tapioca Root.

In India, Sago was produced first in Salem (Tamilnadu). About in 1943-44, Some 50 years ago, sago production started on a cottage scale basis in India by pulping the tapioca roots, filtering the milk-extract and after settling the milk Tapioca Root is the basic raw material for Sago and starch.

The Root, received from the farms are hygienically cleaned in water & after peeling the skin, it is crushed, allowed to pass the milk after retaining all fiber & impurities. The milk is going to settle in a tank for nearly 3 to8 hours, thus all residual impurities float to the top of the tank & are drained out of the settled milk. From this settled Milk Cake, Globules is being made by a very special & unique type system on very simple indigenous machine. After sizing the globules by filtering through sieve, It is Roasted on Hot plates or Heated in steam, depending upon the desired final product as Sago in globular shape.

Roasted Sago is known as Sago Common and Boiled Sago as Nylon Sago.

Objective of this study is to utilize the sago waste in a bio digester to produce biogas which will be the alternative fuel for their kitchen energy need. This work was carried out to produce biogas in a Compact Water Plastic Tank with a fixed type, using sago waste from the sago production plant.

Effect of sago waste on environment
The characteristics of sago waste vary considerably depending upon the types of tapioca, chemicals used for treating the tapioca and processing them. Sago waste is characterized mainly by the measurement of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS) and Total Dissolved Solids (TDS), Sulphides, Chromium, Chloride, p_H, Alkalinity and Acidity.

Solids
The solids to be found in effluent fall into several distinct categories.

Permanganate Value (PV 4 hours)
This technique is occasionally used and depends upon chemical oxidation provided by potassium permanganate. COD determination has almost completely replaced this method. Acid to form ammonium compounds. In a second stage, the ammonia is released on being boiled with sodium hydroxide, and subsequently trapped in a boric acid solution. The level of ammonia released is determined by titration, and its value calculated as nitrogen.

Ammonium content as Nitrogen (N)
Often confused with TKN, this value is sometimes required in discharge limits and. As ammonium compounds are part of TKN, the problems associated with rapid plant growth and oxygen demand are the same. These compounds are mostly the outcome of the deliming process, with comparatively small volumes being produced from liming and unhairing. The analysis is similar to TKN, but omits the initial digestion stage. This excludes the nitrogen component resulting from

protein wastes.

Sulphide (S^{2-})

The sulphide content in effluent results from the use of sodium sulphide and sodium hydrosulphide, and the breakdown of hair in the unhairing process.

Neutral salts

Two common types of salts are to be found in effluent.

Sulphates (SO_4^{2-})

Sulphates are a component of effluent, emanating from the use of sulphuric acid or products with a high (sodium) sulphate content. Many auxiliary chemicals contain sodium sulphate as a by product of their manufacture. For example, chrome processing powders contain high levels of sodium sulphate, as do many synthetic retanning agents. An additional source is created by removing the sulphide component from effluent by aeration since the oxidation process creates a whole range of substances, including sodium sulphate. These sulphates can be precipitated by calcium-containing compounds to form calcium sulphate which has a low level of solubility. Problems arise with soluble sulphates, however, for two main reasons:

a. Sulphates cannot be removed completely from a solution by chemical means. Under certain biological conditions, it is possible to remove the sulphate from a solution and bind the sulphur into microorganisms. Generally, however, the sulphate either remains as sulphate or is broken down by anaerobic bacteria to produce malodorous hydrogen sulphide. This process occurs very rapidly in effluent treatment plants, sewage systems and water courses, if effluents remain static. This bacterial conversion to hydrogen sulphide in sewage systems results in the corrosion of metal parts, and unless sulphate-resistant concrete will gradually erode.
b. If no breakdown occurs, the risk of increasing the total concentration of salts in the surface water and groundwater runs is incurred. Sulphate analysis is performed by adding barium chloride solution to a sample of filtered effluent. The sulphates are precipitated as barium sulphate and filtration; drying and calculation can determine the sulphate level.

Chlorides (Cl^{--})

Chloride is introduced into effluents as sodium chloride usually on account of the large quantities of common salt used in hide and skin preservation or the pickling process. Being highly soluble and stable, they are unaffected by effluent treatment and nature, thus remaining as a burden on the environment. Considerable quantities of salt are produced by industry and levels can rapidly rise to the maximum level acceptable for drinking water. Increased salt content in groundwater, especially in areas of high industrial density, is now becoming a serious environmental hazard.

Chlorides inhibit the growth of plants, bacteria and fish in surface waters; high levels can lead to breakdowns in cell structure. If the water is used for irrigation purposes, surface salinity increases through evaporation and crop yields fall. When flushed from the soil by rain, chlorides re-enter the eco-system and may ultimately end up in the ground water. High salt contents are only acceptable if the effluents are discharged into tidal/marine environments.

The level of salt as chloride under acid conditions can be determined by titrating a known volume of effluent with a silver nitrate solution, using potassium chromate as an indicator. Under neutral or alkaline conditions, excess silver nitrate is added. This excess is then determined by retro-titration with potassium thiocyanate, using ferric alum as the indicator.

Oils

During sago manufacture, natural oils are released from within the skin structure. If fat liquor exhaustion is poor, some fatty substances may be produced through inter-reaction when waste waters mingle.

Floating fatty particles agglomerate to form ‘mats’ which then bind other materials, thus causing a potential blockage problem especially in effluent treatment systems. If the surface waters are contaminated with grease or thin layers of oil, oxygen transfer from the atmosphere is reduced. If these fatty substances emulgate, they create a very high oxygen demand on account of their bio-degradability.

The presence of oil is determined by shaking the effluent sample with a suitable solvent and allowing the solvent to separate into a layer on top of the effluent. This solvent dissolves fatty matter, and a quantity can be drawn off and evaporated until dry.

P^H value

Acceptable limits for the discharge of waste waters to both surface waters and sewers vary, ranging between from P^H 5.5 to 10.0. Although stricter limits are often set, greater tolerance is shown towards higher P^Hsince carbon dioxide from the atmosphere or from biological processes in healthy surface water systems tends to lower P^H levels very effectively to neutral conditions. If the surface water P^H shifts too far either way from the P^H range of 6.5 - 7.5, sensitive fish and plant life are susceptible to loss.

Municipal and common treatment plants prefer discharges to be more alkaline as it reduces the corrosive effect on concrete. Metals tend to remain insoluble and more inert, and hydrogen sulphide evolution is minimised. When biological processes are included as part of the treatment, the pH is lowered to more neutral conditions by carbon dioxide so evolved.

Dissolved Oxygen

The determination of dissolved oxygen present in sewage is very important, because while discharging the treated sewage into river stream, it is necessary to ensure atleast 4ppm of DO in it, as otherwise, fish are likely to be killed, creating nuisance near the vicinity of disposal to ensure this, DO test are performed during sewage disposal treatment processes.

It is well known by now, that only fresh sewage contains some dissolved oxygen which is soon depleted by aerobic decomposition. Also the dissolved oxygen in fresh sewage depends upon temperature. If the temperature of sewage is more DO content will be less. The solubility of oxygen in sewage is 95% of that in distilled water.

The DO content of sewage is generally determined by Winkler’s method which is an oxidation reduction process carried out chemically to liberate iodine in amount equivalent to the quantity of dissolved oxygen originally present.

Other Metals

Other metals which might be discharged from sago waste and whose discharge may be subject to statutory limits include iron and zirconium.

Depending on the chemical species, these metals have differing toxicities that are also affected by the presence of other organic matter, complexing agents and the p_H of the water. Aluminium, in particular, appears to inhibit the growth of green algae and crustaceans are sensitive to low concentrations. Cadmium, sometimes used in yellow pigments, is considered highly toxic. It is accumulative and has a chronic effect on a wide range of organisms. If present in drinking water, it can induce brittleness in bones.

- **Purpose of waste water treatment and recycling**

Manufacturing of sago, sago products, produces numerous by-products, solid wastes, high amounts of wastewater containing different loads of pollutants and emissions into the air. The uncontrolled release of effluents to natural water bodies increases health risks for human beings and environmental pollution. Effluents from raw hide processing sago, which produce wet white, or finished sago contain compounds of trivalent chromium (Cr) and sulphides in most cases. Organic and other ingredients are responsible for high BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) values and represent an immense pollution load, causing technical problems, sophisticated technologies and high costs in concern with effluent treatment.

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal (as in slow-rate land treatment). However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture. The quality of treated effluent used in agriculture has a great influence on the operation and performance of the wastewater-soil-plant or aquaculture system. In the case of irrigation, the required quality of effluent will depend on the crop or crops to be irrigated, the soil conditions and the system of effluent distribution adopted. Through crop restriction and selection of irrigation systems which minimize health risk, the degree of pre-application wastewater treatment can be reduced. A similar approach is not feasible in aquaculture systems and more reliance will have to be placed on control through wastewater treatment.

A major advantage of anaerobic wastewater treatment is the controlled, continuous production of valuable biogas. The biogas contains 60-85% methane and is a valuable energy source. The closed anaerobic process systems also prevent large quantities of methane (an important greenhouse gas) being emitted to atmosphere. Biogas is the ultimate waste product of the bacteria feeding off the input biodegradable feed stock and is mostly methane and carbon dioxide, with a small amount hydrogen and trace hydrogen sulphide.

Scope of present study

- Solid and liquid waste of sago is collected from sago production plant and its characteristics has been studied.
- Before discharging waste water to water bodies it has to be treated to reduce the Chemical Oxygen Demand, Chromium content.
- As a result of this treatment Biogas liberated can be used for domestic purpose.
- The amount of land fill has also been considerable reduced.

- **Anaerobic Reaction**

An anaerobic organism or anaerobe is any organism that does not require oxygen for growth. It could possibly react negatively and may even die if oxygen is present. There are three types:

- Obligate Anaerobes, which cannot use oxygen for growth and are even harmed by it
- Aero tolerant Organisms, which cannot use oxygen for growth, but tolerate the presence of it
- Facultative Anaerobes, which can grow without oxygen but can utilize oxygen if it is present

Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen. It is used for industrial or domestic purposes to manage waste and/or to release energy.

The digestion process begins with bacterial hydrolysis of the input materials 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.

It is used as part of the process to treat biodegradable waste and sewage sludge. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. Anaerobic digesters can also be fed with purpose-grown energy crops, such as maize.

Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases. This biogas can be used directly as cooking fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane. The use of biogas as a fuel helps to replace fossil fuels. The nutrient-rich digestate also produced can be used as fertilizer.

The technical expertise required to maintain industrial-scale anaerobic digesters, coupled with high capital costs and low process efficiencies, has so far been a limiting factor in its deployment as a waste treatment technology.

Advantages of anaerobic digestion

- Produces large amount of methane gas. Methane can be stored at ambient temperature.
- Produces free flowing, thick liquid, sludge.
- Sludge has good fertilizer value and can be used as soil

conditioner.
- Reduces organic content of waste material by 30 – 50%.
- Provides a sanitary way disposal of human and animal waste.

Disadvantages of anaerobic digestion
- Possibility of explosion.
- High capital cost.
- Maintenance control is required.

Objectives of the present study
Anaerobic treatment is clearly suitable for India's tropical climate. The reduced cost brought about by lower power consumption are generally enough among all the waste treatment methods even if any returns of gas utilization are neglected.

UP flow anaerobic sludge blanket (UASB) reactors
The UASB is a high rate suspended growth in which a pre-treated raw influent is introduced into the reactor from the bottom and distributed evenly. "Flocs" of anaerobic bacteria will tend to settle against moderate flow velocities. The effluent passes upward through, and helps to suspend, a blanket of anaerobic sludge. Particular matters is trapped as it passes upward through the sludge blanket, where it is retained and digested.
Digestion of the particular matter retained in the sludge blanket and breakdown of soluble organic materials generate gas and relatively small amounts of new sludge. The rising gas bubbles help to mix the substrate with the anaerobic biomass.
The biogas, the liquid fraction and the sludge are separated in the gas/solid/liquids phase separator, consisting of the gas collector dome and a separate quiescent settling zone. The settling zone is relatively free of mixing effect of the gas, allowing the solid particles to fall back into the reactor, the clarified effluent is collected in gutters at the top of the reactor and removed. The biogas has methane content typically around 75% and may be collected and used as a fuel or flared.

Environmental Benefits
- **Reduce methane from landfills**

When sago waste is disposed in a landfill it rots and becomes a significant source of methane - a potent greenhouse gas with 21 times the global warming potential of carbon dioxide. Landfills are a major source of human-related methane in the United States, accounting for more than 20 percent of all methane emissions.

- **Reduce resource use associated with sago production**

There are many resources needed to grow tapioca, including water, fertilizers, pesticides, and energy. By wasting it, you are also wasting the resources that when into growing it. Additionally, 14 percent of greenhouse gases in the United States are associated with growing, manufacturing, transporting, and disposing of tapioca. By reducing the amount of sago wasted, we can reduce greenhouse gas emissions.

- **Create a valuable soil amendment**

Recycling sago waste and turning it into compost has many environmental benefits such as improving soil health and structure; increasing drought resistance; and reducing the need for supplemental water, fertilizers, and pesticides. sago waste can also be turned into renewable energy and a soil amendment through anaerobic digestion.

- **Improve sanitation, public safety, and health at your facility**

Sago waste dumped in standard trash cans and dumpsters in the back alley of a home, store or restaurant can generate bad odors and attract rodents or insects. Placing tapioca scraps in a closed, leak-proof, durable, and reusable container, and having it frequently emptied for donation or composting can significantly reduce, and even eliminate these problems.

Sample Collection
Samples for treatment of sago waste, both solid and liquid were collected from sago production plant, mattayampati. About 50 litres of waste items were collected and waste water which mixing together, forms semi solid state.

Fig 1: Cycle with multi benifites.

Materials
The semi solid waste used in this study is collected from sago production plant. The fresh Cow Dung Slurry was added to the above sago waste to supplement the reaction process. It is used as a seeding material for the reaction process in the UASB (Upflow Anaerobic Sludge Blanket Reactor). Effective micro organism collected from private company was used to accelerate the reaction process. Also yeast is added for fermentation process to take place.

Setup of anaerobic reactor (UASB Reactor)

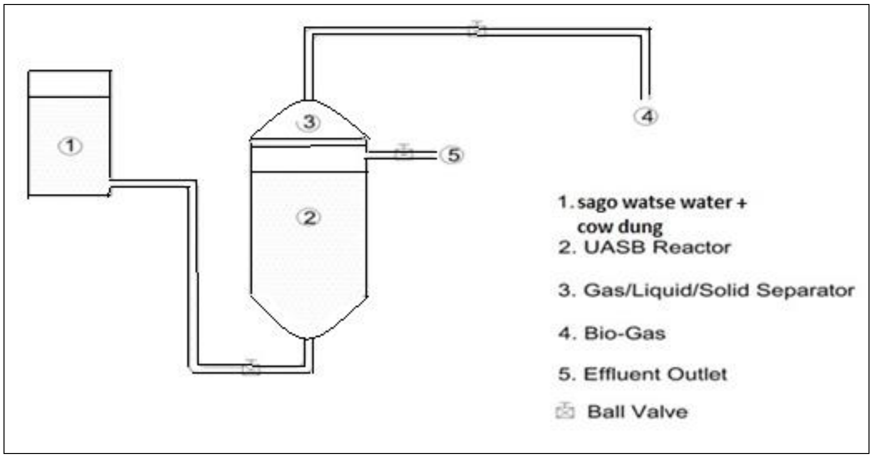

Fig 2: Diagram of UASB reactor

Fig 3: UASB reactor before production of biogas

Fig 4: UASB reactor after production of biogas

Fig 5: Weight of the ballon

Fig 6: Weight of the ballon with bio-gas

Fig 7: Burning of bio-gas filled in the ballon

The chemical parameters of sago waste was studied

P^H Test

Chemical Parameters

- Rinse each test tube with the water sample. Gloves should be worn to avoid skin contact with the water.
- Fill the tube to the 5mL line with sample water.

- While holding a dropper bottle vertically, add 10 drops of Wide Range Indicator Solution.
- Cap and invert several times to mix.
- Insert the tube into the Wide Range pH Comparator. Hold the comparator up to a light source. Match the sample color to a color standard.
- Record the pH value.
- Wash your hands.

Bod Test
- Fill two dissolved oxygen bottles (one clear and one black) with sample water, holding them for two to three minutes between the surface and the river bottom. If sampling by hand remember to use gloves.
- Prepare the clear sample bottle according to the directions for the dissolved oxygen test. Determine the DO value for this sample in mg/L.
- Place the black sample bottle in the dark and incubate for five days at 68'F (20'C). This is very close to room temperature in many buildings. If there is no incubator, place the blackened sample bottle in a "light-tight" drawer or cabinet.
- After five days, determine the level of dissolved oxygen (in mg/L) of this sample by repeating steps four through eleven of the DO testing procedure.
- The BOD level is determined by subtracting this DO level from the DO level found in the original sample taken five days previously:
- BOD=mg/LDO(original-sample)-mg/LDO(after incubation)
- The BOD measure is, the amount of oxygen consumed by organic matter and associated microorganisms in the water over a five-day period.

Cod Test
- Turn on Tube tests heater, set the control to 150°C and place the safety shield in position. Allow the heater to heat up to temperature.
- Prepare the sample tube as follows. Shake tube vigorously to suspend all sediment. Remove the cap of the COD Tubetests tube. Add 2 ml of sample (150 and 1,500 ranges), or 0.2 ml of sample (15,000 range), using a Plain test pipettor disposable tip dispenser or a standard laboratory pipette.
- Replace the cap tightly and invert tube gently to mix contents. The tubewill become hot on mixing. Ensure all of the precipitate is suspended before proceeding. Label the tube using the labels provided in the reagent pack and place the tube in the Tubetests heater. Ensure the safety screen is in position.
- Prepare a reagent blank by repeating steps 2 and 3 using 2 ml (150 and 1,500 ranges), or 0.2 ml (15,000 range) of deionised or distilled water in place of the sample. This stage may be omitted if a suitable reagent blank tube is already available.
- Digest the tubes for two hours then turn off the heater unless it is required for further tests.
- Carefully remove each tube, invert gently to mix and then transfer to a test tube rack.
- Allow the tubes to cool to room temperature.
- Select appropriate wavelength on photometer.
- Take the photometer reading

Test for acidity
- Take 20ml of sample in a clean conical flask.
- Add 2 drop of methyl orange indicator and the solution turns orange red colour.
- Titrate the sample with standard NaOH solution (0.02N) which is taken in burette.
- The end point is the appearance of yellow colour from orange red colour.
- Then to the same solution, add 2 drops of phenolphthalein indicator to the solution and titrate the sample against standard NaOH added is noted and it is taken as final endpoint.
- The total volume of NaOH added is noted and it is taken as final endpoint.
- Repeat the procedure to get concordant value.

Test for alkalinity
- **Reagent Preparation**

Dilute 28ml of conc. H2So4 to one litre (0.1N) from that take 200ml of 0.1N H2So4 and dilute to one litre (0.02N).

- **Phenolphthalein Indicator**

- Take 20ml of sample in a clean conical flask.
- Add 1 drop of phenolphthalein indicator and the sample will be in pink colour.
- Titrate the sample with standard sulphuric acid (0.02N) which is taken in burette.
- The end point is the appearance of pink colour.

- **Total Alkalinity**

- Add 1 drop of methyl orange indicator to the solution in which phenolphthalein alkalinity has been determined.
- Titrate the above sample against standard HCl (0.02N).
- The end point is the appearance of pink colour.
- Repeat the procedure to get concordant value.

Chloride
- Take 20ml of the given sample in a conical flask.
- Add 2 to 3 drops of potassium chromite indicator to get light yellow colour.
- Titrate the sample against silver nitrate solution until the colour changes from yellow to brick red
- The same procedure is repeated until concordant values are obtained

Sulphate
- Measure 50 ml of sulphate in a beaker.
- Add 10 ml of 2NHcl to it.
- Boil the contents while boiling 30 ml of 40% $Bacl_2$ solution and filter precipitate with distilled water.
- Wash the precipitate with distilled water.
- Burn the paper at 800° C after transferring to silica crucible.
- Heat the filter paper until no black particle appears.
- Silica crucible is cooled and weight.

Fig 8: Filtrating sample for sulpthate test

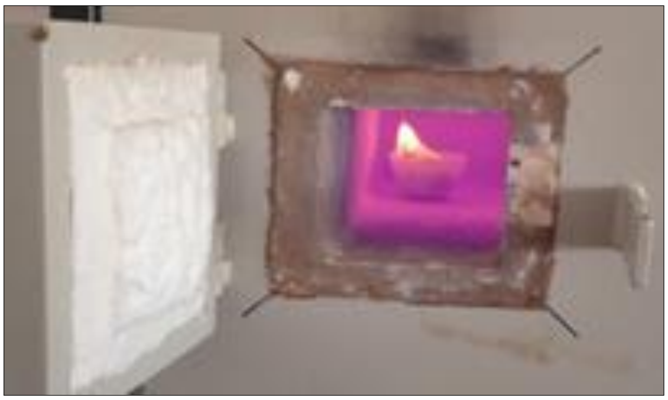

Fig 9: Burning residues in oven for sulphate test

Dissolved Oxygen

- Fill sample on BOD bottle.
- Add 2 ml of manganese sulphate and potassium iodide solution to it.
- Add few drops of sodium thio sulphate to it.
- Place the stopper and shake the contents well by inverting the flask.
- Keep the flask for some time without any disturbance to form precipitate.
- Add 2 ml of concentrated H_2SO_4 and shake the bottle well to dissolve the precipitate.
- Then leaving the solution to yellow.
- Take 100 ml of this sample and titrate it against sodium thio sulphate using starch as indicator.
- The solution turns blue.
- End point is change of colour from blue to colourless solution.

Table 1

S. No	Parameters	Chemical characteristics of		
		Sample 1	Sample 2	Sample 3
1	PH	7.5	7.2	7
2	T. Alkalinity mg/l	498	230	123
3	T. Acidity mg/l	Nill	Nill	Nill
4	Dissolved oxygen mg/l	2.8	1.2	0.5
5	COD mg/l	28000	12650	6583
6	BOD mg/l	9200	5060	2240
7	Chloride mg/l	878.84	434.55	242.45
8	Sulphate mg/l	3606.3	1644.66	822.46

Table 2

S. No	Parameters	0-30 days	30-60 days	60-90 days
1	PH	7.5	7.2	7
2	T. Alkalinity mg/l	498	230	123
3	T. Acidity mg/l	498	230	123
4	Dissolved oxygen mg/l	2.8	1.2	0.5
5	COD mg/l	28000	12650	6583
6	BOD mg/l	9200	5060	2240
7	Chloride mg/l	898.84	434.55	242.45
8	Sulphate mg/l	3606.3	1644.66	822.46

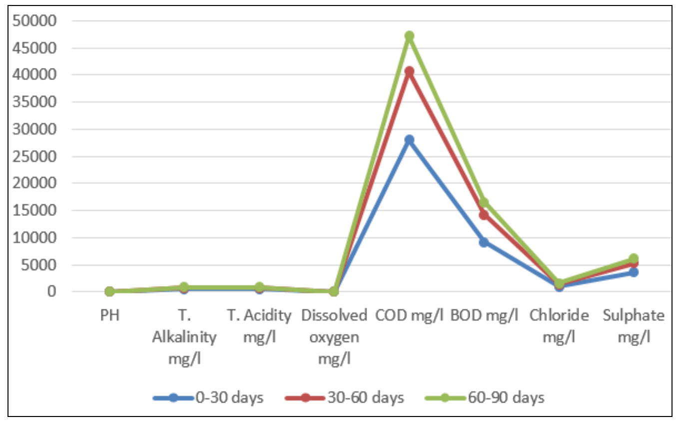

Fig 10

Conclusion

Based on the performance evolution of acedogenic reactor and UASB reactor the following collusion have been drawn. Anaerobic sludge reactor can be started successfully in 90days sago waste is treated. This indicates that the waste has better anaerobic biodegradability at the suitable chemical oxygen demand. The conditions of digestion in anaerobic sludge reactor are as follow: At the bottom of anaerobic sludge reactor, the macromolecular organic matter has been biodegraded into smaller molecular organic acid by acid-producing bacteria, and among which, the highest proportion is acetic acid followed by propionic acid, iso-butyric acid and iso-valeric acid.

Along the whole length of anaerobic sludge reactor, methanogen gradually converts the organic acids into the methane gas and carbon dioxide, to achieve a waste of resource utilization. The results show that anaerobic sludge reactor can treat sago waste with high contaminated load. A considerable rate of decrease has been found out in the values of COD, BOD, pH, Alkalinity and Acidity. As a result of the treatment of sago effluent using USAB reactor. Bio-Gas production has been seen, which is a useful bi product.

References

1. Yabfang NIU, Xingyuan MA, Rui Wang, Congzheng YU. Treatment of high density sago effluent by USAB process. 2009, 1-6.
2. Durai G, Rajasimman M. Kinetic studies on biodegradation of wastewater in a sequential batch bioreactor. 2011; (3):19-26.
3. Nayana Kumar Behera. Treatment of Industrial Effluents

in am Bioreactor, 2009, 20-302.
4. Lihui Huang, Baoyu Gao, Peng Guo, Zhang BO. Application of anaerobic granular sludge to treatment of fishmeal industry wastewaters under highly saline conditions, 2009, 433-437.
5. Wang Bing, Han Hong jun, Tian Wende, Liu Shuo, Ma Wencheng. Study on Anaerobic Granular Sludge in Beer Waste Water Treatment. 2009, 1027-1031.
6. Xinmei Fu, Nges Ivo Achu, Emma Kreuger, Lovisa Björnsson. Comparison of Reactor Configurations for Biogas Production from Energy Crops, 2010, 1-4.
7. Rameshraja D, Suresh. S. Treatment of sago Wastewater by Various Oxidation and Combined Processes. 2001; 5(2):349-360.
8. Yong Gao. UASB Treatment of Monosodium glutamate Wastewate, 2008, 1-4.
9. Lu WANG, Yong-feng Li. Biohydrogen production and wastewater treatment by anaerobic fermentation with UASB Process, 2001, 1-4.
10. Yi Sun, Yu-wen Li. The techology of wastewater treatment and Energy recovery based on UASB reactor, 2010, 1-4.
11. Xingyuan Ma, Qi Liu, Jun Ma. Study on the Inhibitory Effect of Mimosa Extract on Anaerobic Fermentation. 2011, 1169-1172.
12. Bryers Ld, Mason EA. Biopolymer particulate turnover in biological waste treatment systems: a review. Bioprocess Eng. 1987; 2:95-109.
13. Valentni A, Garut G, Rozzi A. Analisi delle cinetiche di degradazione anaerobicadel particulate organico e difinizione diunnuovo approcioallo studio. IA Ingegneria Ambientale. Y:z. (J n Italian). 1996; 25:44-52.
14. Valentini A, Grant G, Rozzi A. Anaerobic degradation kinetics of particulate organic matter: a new approach. Water Sci. Techno. 1997; 36:239-246.
15. Halalsheh M, Sawajneh Z, Zubi M, Zeeman G, Lier l, Fayyad M, Lettinga G. Treatment of strong domestic sewage in a 96 m3 UASB reactor operated at ambient temperatures: two-stage versus single-stage reactor. Biores. Techno. 2005; 96:577-585.
16. Uemura S, Harada H, Ohashi A, Torimura S. Treatment of wastewater containing large amount of suspended solids by a novel multi-staged UASB reactor. Environ. Techno. 2005; 26:1335-1362.
17. Zhang LL, Zhang 8, Huang YF, Cai WM. Application of aerobic granular sludge in polishing the UASB effluent. Environ. Techno. 2005; 26:1327-1334.
18. Verstraete W, Tanghe T, De Smul A, Grootaerd H. Anaerobic biotechnology for sustainable waste treatment. In: Sayler (ed) Biotechnology in the sustainable environment. Plenum Press, New York. 1997; 359:343-359.
19. Cavalcanti PFF, Medeiros EJS, Silva Lkm, Van Haandel A. Excess sludge discharge frequency for UASB reactors. Water Sci.
20. Xingyuan Ma, Congzheng Yu, Xiaoxing Li. Main factors of sago waste water treatment by UASB. Technology of Water Treatment. 31. (In Chinese). 2005; (7):66-68.
21. Tusuo Geng. New technics of sago waste water treatment. Guizho Environmental Protection Science and Technology. 10. (In Chinese. 2004; (1):21-26.