Anaerobic Baffled Reactor-A Sustainable Approach for Coconut Husk Retting

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Abstract- Retting is a process of immersion of coconut husks in water for manufacture of good quality coir fiber. Open retting of coconut husks in water bodies is the conventional method which causes serious environmental problems due to emission of green house gases. The pollution due to open retting practice accounts to biodegradable COD and large quantities of non-biodegradable poly phenols in the retting water bodies. This has been affecting natural heritage of rich biodiversity in the backwater bodies. Mechanical and chemical methods for extraction of fiber are found not to be feasible solutions because of low quality and economics. Closed retting, an alternative to open retting is a process in which soaking liquor is treated in a high rate anaerobic reactor. In this retting method biodegradable organics are converted to VFA fractions like acetic, propionic and butyric acids and finally to CH_4. There is no sulphide generation in this process as fresh water can be used for producing quality fibers. The present study analyses the performance of an anaerobic baffled reactor (ABR) in the treatment of husk soaking liquor. A laboratory scale Anaerobic Baffled Reactor and retting tank was fabricated and the efficiency of the system was evaluated by analyzing the parameters like, Alkalinity, pH, COD and total Suspended Solids etc. The analysis indicated favourable atmosphere for anaerobic reaction within the reactor and he working performance of anaerobic baffled reactor in the treatment of husk liquor is found to be satisfactory.

Index Terms-: Anaerobic Baffled Reactor, Closed retting, Coir husk, UASB

I. INTRODUCTION

A. General

Coconut fiber is a coarse and durable natural fiber extracted from the outer shell of a coconut fruit. The scientific name of coconut fiber is Cocos nucifera. Brown fibers extracted from matured coconuts are thick, strong and have high abrasion resistance while white fibers extracted from immature coconuts are smoother and finer and also weaker. Coir fibers range in length from 10-30 cm and is utilized for manufacture of various products like coir yarn, coir mats, coir geotextiles etc. Among the natural geotextiles, coir geotextiles are considered as the most durable one because of high lignin content of coir fiber and hence its demand is increasing day by day for various engineering applications [1].

Chemically, coir is composed of cellulose, lignin, pectin and hemicellulose, the percentage of which varies very much depending upon the age of the nut, from which the coir is derived. Open retting is an age-old practice for the extraction of coir from coconut husks by immersing them in natural water bodies for a period of nearly one year. Retting of coconut husk is the basic process in the manufacture of coir, the golden fiber which is used for a variety of purposes. The coconut husk which represents the entire fibrous material covering the fruit constituting both the mesocarp and exocarp is the raw material for the coir industry. During retting in water leathery exocarp is separated from the fibrous mesocarp. The elastic cellular cork like material forming the non-fibrous tissue of the husk is referred to as coir pith and accounts for a larger portion of the total weight of the husk.

Coir industry is one of the major agro-based industries of Kerala state contributing notable job opportunities to the rural communities. Coconut husk retting is prevalent along the coastal belt of Kerala, where back waters are usually used for soaking the husk. During retting large quantities of organic matter, both biodegradable and non-biodegradable, and colloidal substances release into water making the water turbid and blackish. The concentration of dissolved oxygen is reduced largely as it is used for the biological degradation of organic matter and oxidation of non-biodegradable substances. Also during retting large quantities of phenolic substances are leached out into waters which cause extensive damage to the aquatic flora and fauna. Backwater retting causes extinction of many species of fishes leading to economical loss to fishermen community [4].

The sulphates present in retting water are reduced to H_2S and is recognized as a major health problem like Bronchitis, Headache and Asthma. Various types of skin diseases are also reported among local people. In addition to these, coir extraction causes the formation of large quantities of coir pith, giving rise to disposal problems[6].

To overcome the problems of open retting mechanical methods of fiber extraction are employed in which method, dry husks are soaked in cement tanks for a period varying from a few hours to three weeks and fiber is extracted mechanically. The fiber produced by this method is inferior in quality. Added with the disadvantages of greater energy consumption and large quantity of pith production.

After years of research, the Central Coir Research Institute Kerala has developed a microorganism called Coir Ret or Ret Plus to reduce the retting period. These micro-organisms grow in the coconut husk. Therefore the retting process is faster using ret plus. It also helps to improve the quality of fiber. Even though the pollution of back water due to open retting is reduced, huge quantity of ret liquor is disposed into water sources without proper treatment, polluting them in the due course.

In order to eliminate the problems due to disposal of ret liquor into natural water sources a method is to be introduced in which the ret liquor is treated within the system itself. In recent years numerous designs have been developed for anaerobic treatment of wastewater. Up-flow Anaerobic Sludge Blanket (UASB) process is currently the most widely used treatment system among the presently available treatment process Closed Coir Retting is a zero discharge technology developed by National Institute for Interdisciplinary Science and Technology (NIIST) Thiruvananthapuram, Kerala, India based on the principle of UASB [5].

B. *Process Of Closed Retting*

*T*he important part of closed retting is a biological leaching bed, which provides removal of bio-extractable components from coconut husks and thereby achieves anaerobic degradation of the bonding between the fiber and matrices(Manilal, 2004). The leached pollutants are pumped to a coupled high rate anaerobic reactor (UASB). The microbial consortia convert the dissolved biodegradable organics to volatile fatty acids like acetic (71%), propionic (19%) and butyric acids (10%) and finally to CH_4. The CH_4 yield through closed retting for a ton of coir fiber is $490m^3$. There is no sulphide generation in this process as fresh water can be used for producing quality fibers. Biogas thus produced from the reactor can be collected and used as fuel. The low sulphate level in retting water reduces the growth of sulphate reducing bacteria and biogas is substantially free of H_2S. Closed retting requires about 30 days against 10 months of open retting. It is a labour friendly and zero discharge process. Very small quantity of waste material produced in this method can be used as a soil conditione [5]). Even though the methodology of UASB is very effective for problem free coir retting, the installation of tall UASB structures faces difficulties during installation especially in water logged areas.

C *Anaerobic Baffled Reactor*

Anaerobic Baffled Reactor (ABR) is a type of high rate anaerobic reactor developed by McCarty and co-workers at Stanford University. ABR is described as a series of up flow anaerobic sludge blanket reactors (UASBS) because it is divided into several compartments and each compartment function like a UASB reactor, where the wastewater arises upwards through a blanket of active biomass sludge. ABR was reported to be effective for the treatment of various industrial effluents [7]. A typical ABR consists of a series of vertical baffles that direct the wastewater under and over the baffles as it passes from the inlet to the outlet. The over and underflow of the liquid reduces bacteria washout. Advantages of ABR include simplicity in design, inexpensive in construction, low hydraulic retention time, high solid retention time and intermittent operation. The present study explores the suitability of Anaerobic Baffled Reactor for closed retting of coconut husk to overcome the practical difficulties in field installation of UASB reactor.

II. EXPERIMENTAL SETUP

A. *Anaerobic Baffled Reactor (ABR)*

A vessel made up of mild steel having a size 115cm x 77cm x 47cm was used as ABR in the study. The working volume of reactor is 354 litre. The vessel was compartmentalized by providing baffle plates of height 40cm. The baffle plates were located at 43cm, 67 cm and 91 cm distance from the inlet side. Fig. 1 shows the ABR used in the study.

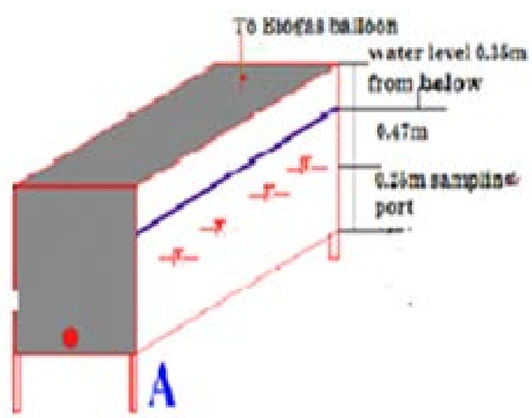

Fig. 1 Anaerobic Baffled Reactor

B. *Retting Tank*

A square tank of size 50cm x 50cm x 50cm having a gas tight cover made up of GI sheet was used as retting tank (Fig.2). An inlet port of 2.5 inch and an outlet port of 2.5 inch were provided for the recirculation of retting liquor. A gas port of 0.25 inch was provided for the collection of Biogas generated. Water depth in the retting tank was maintained as 35 cm and its working volume was 87.5 litre.

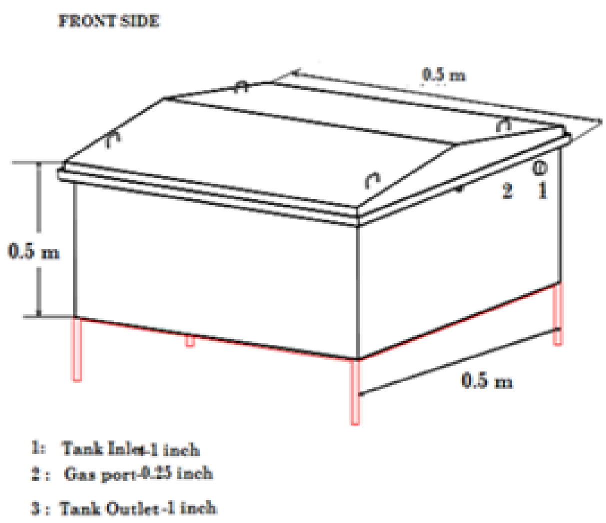

Fig.2. Retting tank

C. *Recirculation Pump*

A recirculation pump of 0.25 HP having a pumping capacity of 35 LPM was provided to recirculate the retting liquor from the retting tank into the ABR and back.

D. *Experimental Procedure*

Initially 10 litre of canteen waste digester sludge was added to the first compartment of ABR. The retting tank and the reactor were filled up to working volume with tap water. Recirculation pump was started and continuously run for four hours per day for two days. Fig.3 shows the circulation of ret water in and out of the reactor and retting tank. Distribution of sludge in reactor compartments and retting tank were checked by determining the Total Suspended Solids (TSS).

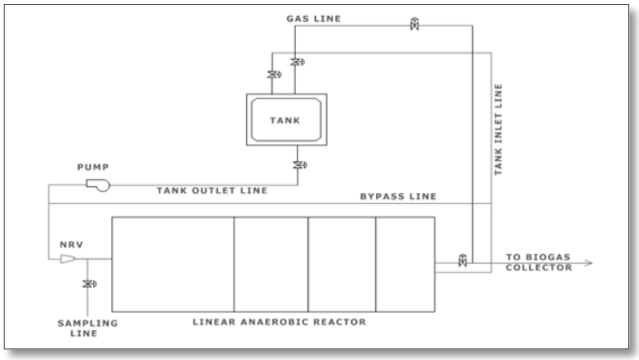

Fig 3 : Flow of ret liquor in experimental setup

5 kg of green coconut husk collected from 11 month old coconuts were used for the study. Initial moisture content of the husk was determined. After crushing, the husks were stacked in the retting tank and 20 litres of canteen waste sludge was added into the retting tank. The soaking liquor from the retting tank was pumped into Anaerobic baffled Reactor for 4 hours per day. Samples of retting liquor were taken from the retting tank outlet and from ABR compartments at regular intervals of 48hours. These samples were analyzed to study the characteristics such as TSS, pH, alkalinity and COD. The recirculation of soaking liquor stopped and the husks were taken out. when the COD concentration decreased and stabilized to a minimal value.

III RESULTS AND DISCUSSIONS

A. *pH Profile*

Fig 3 shows the pH variation of influent and effluent with time. An optimal pH range for smooth running of an anaerobic reactor is 6.6-7.6. Low pH can inhibit acidogenesis and pH below 6.4 can be toxic for methanogens which will seriously affect the anaerobic process. From Table 1 pH was found to be within the range and addition of alkaline substances was not required to raise pH during retting, which means that both the acidogenic and methanogenic bacteria were active throughout the retting process

Table 1:pH value of liquor in reactor and retting tank

Day	RT Out	Comp 1	Comp 2	Comp 3	Comp 4
2	6.69	6.8	6.73	6.7	6.72
10	6.9	6.75	6.74	6.69	6.78
16	7.5	7.73	7.3	7.52	7.22
20	7.1	7.34	7.4	7.13	7.4
26	6.81	6.79	6.89	6.89	6.88
30	6.9	7	6.67	6.67	6.59

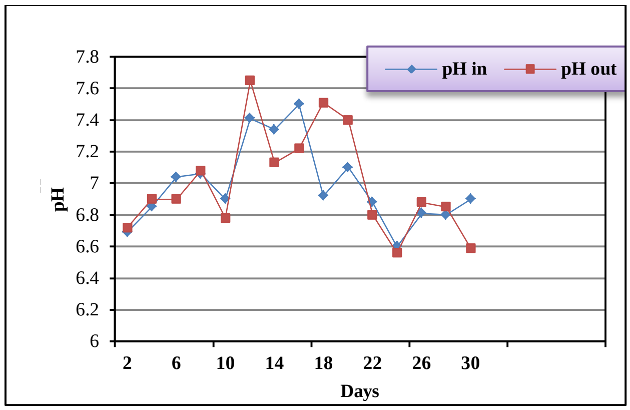

Fig 4: Variation of pH with time

B.Alkalinity Profile

Alkalinity measurements are extensively used to judge the general conditions of the anaerobic reactor. In a properly operating anaerobic reactor, pH is maintained by the bicarbonate buffer system as a result of the production of CO_2 and release of positively charged ions into the solution during decomposition of the organic compounds. Measurement of pH alone is not sufficient as a control technique.When most of the bicarbonate alkalinity has been consumed, pH will fall out of the proper range. Thus, the primary control tests during anaerobic digestion are volatile acid concentration and alkalinity. Fig 5 shows the alkalinity variation with time. It shows that the concentration of alkalinity is in therange of 11.95 meq/l-13.52 meq/l and the VFA/Alkalinity ratio is < 0.2 which shows that during the course of retting no corrective action was required to increase the alkalinity. Almost stable alkalinity concentration during the retting indicates the anaerobic process is normal and no process upsets occur. In all the compartments the alkalinity concentrations are almost equal.

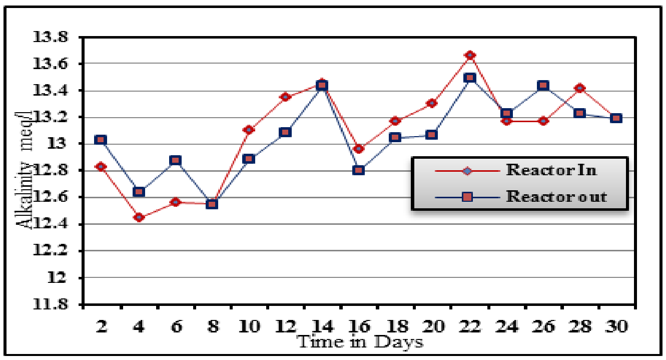

Fig 5: Variation of Alkalinity with time

C. COD profile

COD variation with time is shown in Fig-6. COD removal of 78% was achieved by treating the retting effluent in the Anaerobic Baffled Reactor (ABR). Major portion of COD was removed within ten days of retting period.

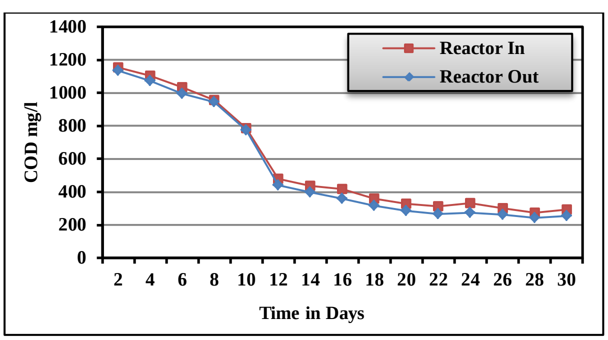

Fig 6: Variation of COD with time

Table 2 provides the COD of ret liquor in retting tank and reactor compartments at different time intervals. It is obserbed that COD removal is taking place throughout the process. The rate of removal is reduced significantly after three weeks. The retting process was stopped after 30days on stabilization of COD.

Table 2: variation of COD in ABR

Day	RT OUT	PORT 1	PORT 2	PORT 3	PORT 4
2	1152.71	1142.86	1123.15	1114.00	1103.01
6	1043.15	1033.90	1014.63	1004.40	995.122
10	784.31	813.73	784.31	764.70	774.51
16	417.48	398.06	388.35	378.64	359.22
20	326.73	316.83	297.03	287.12	287.13
26	302.44	292.68	282.92	273.17	263.41
30	292.68	277.22	263.41	253.65	253.66

D Total Suspended Solids Profile

TSS concentrations in mg/l in diffrent compartments are given in Fig-6. From the figure it is clear that TSS concentration is decreased during the retting process. This shows that suspended solids in the retting liquid is stabilized and settled in the compartments. Provision of baffles prevent the biomass washout and increases the settling capacity.

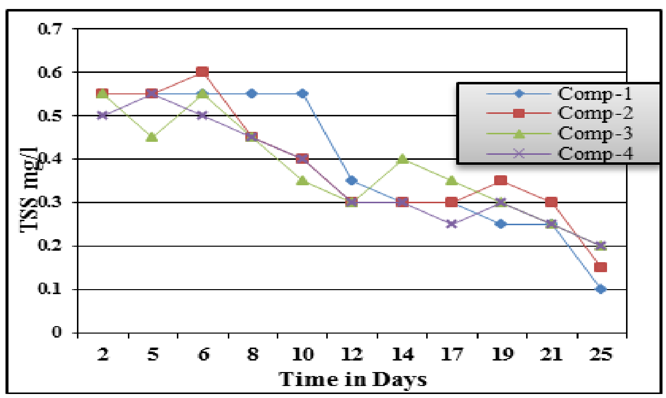

Fig 6: Variation of TSS with time

E VFA profile

Volatile fatty acid concentration in the influent and effluent at different times is graphically represented in Fig-7. In the VFA profile the concentration of VFA is higher during the first two weeks and then decrease gradually, which shows that during earlier stages of retting glucosides, carbohydrates, tannins and nitrogen compounds are leached out of the husk and brought into solution. Acidogenic bacteria convert these compounds into volatile fatty acids such as acetic, propionic and butyric acid. From the VFA profile it is clear that both the acidogenic and methanogenic bacteria are active throughout and the system is stable without any operational problem.

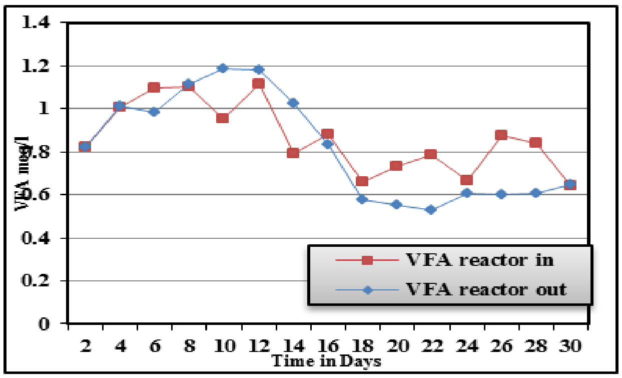

Fig 7: Variation of VFA with time (Reactor inlet and outlet)

F. Quality of Fibre

After completion of retting, the husks are taken out from the retting tank. A sample piece of husk was taken and its initial weight was determined and dried in an oven for 24 hours. The weight of dried sample was determined and fibre and pith were separated. The weight of fibre, pith and pericarp was determined. The tensile strength and modulus of elasticity were determined.The quality of fiber was assessed based on the requirements and found to be good. Table 3 shows the properties of fibre obtained in the study.

Table 3: Physical Properties Of Fibre Extracted By Closed Retting In ABR

Property	**Unit**	**Required value for good quality fiber**	**Fiber properties after retting using ABR**
Fiber length	mm	10-200	75-190
Fiber diameter	mm	0.2-0.6	0.30-0.40
Bulk density	kg/m^3	1400 to 1500	1450
Ultimate tensile strength	N/mm^2	80-125	107
Modulus of elasticity	N/mm^2	18 to 25	22

IV. CONCLUSION

The present study arrives at the following conclusions. Anaerobic baffled Reactor (ABR) is very effective for the treatment of retting liquor. COD removal of 78% wass achieved, which can be considered as a better reduction as the effluent is not discharged and further used for soaking by recirculation. pH of liquid in ABR is within optimal range of 6.5-7.7 which is the recommended range for anaerobic process. The quality of fibre extracted from the retting is fine indicating completion of retting within one month. The retting process is effective without adding nutrients or buffering substances to increase pH. Anaerobic Baffled Reactor may be considered for closed retting process in practical applications, as it is simple to design, requires only low capital investment and operational costs and there is no need of a skilled operator.

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