Commercial Plant for Producing Paper Grade Pulp by a Novel Anaerobic Process

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ABSTRACT

Highly economical commercial plants for processing lignocellulosic wastes for preparing pulp and paper by a biological route have been designed based on pilot plant trials. This patented novel biopulping technology consumes less quantity of chemicals and energy and discharges less toxic effluents making the process ecofriendly.

INTRODUCTION

Paper plays a vital role in the cultural development of mankind. It plays an important role in achieving the social objectives of literacy and communication on one hand and supporting the growth of industrial production and trade on the other hand. The basic raw materials for production of paper are wood and other lignocelluslosic materials[1-8]. All the lignocellulosic materials contain cellulose, hemicellulose and lignin as important constituents which are bound together and renewable in nature. Pulping is the process of liberation of fibres from this bondage by removal of lignin partly or wholly. This is accomplished by either mechanically, chemically or combining these two types of treatments[9].

The common commercial pulping processes can be grouped into four categories namely (I) Mechanical pulping (II) Chemi-mechanical pulping (III) Semi-chemical pulping (IV) Chemical pulping.

Most of the above pulping processes require large quantities of chemicals and energy. Further, the drastic cooking conditions adopted by the paper industry results in generation of a variety of wastes in gaseous and solid phase causing environmental pollution. The high energy input and toxic effluents discharged through these pulping processes have made scientists to investigate ecofriendly and low energy consuming processes for pulping of lignocelluloses. Under such circumstances, biological processes offer an ideal and appropriate solution to the above problems. A large number of fungi and bacteria are found in nature which can degrade the lignin as well as other components of lignocelluloses. These micro-organisms can be employed in softening of the lignocellulosic materials either singly or in combination for partial loosening or removal of lignin so that the total requirement of chemicals and energy for the production of pulp can be minimised to a greater extent.

Bio-pulping therefore, can be defined as the treatment of wood chips with micro-organisms prior to mechanical or chemical pulping. In mechanical pulping, the pretreatment with micro-organisms results in saving of energy and improvement of paper properties, while in chemical pulping, bio-pulping is attempted to reduce the amount of cooking chemicals and increase the cooking capacity which ultimately results in lower consumption of bleaching chemicals in addition to indirect saving on energy and generation of less toxic effluents leading to reduction in environmental pollution.

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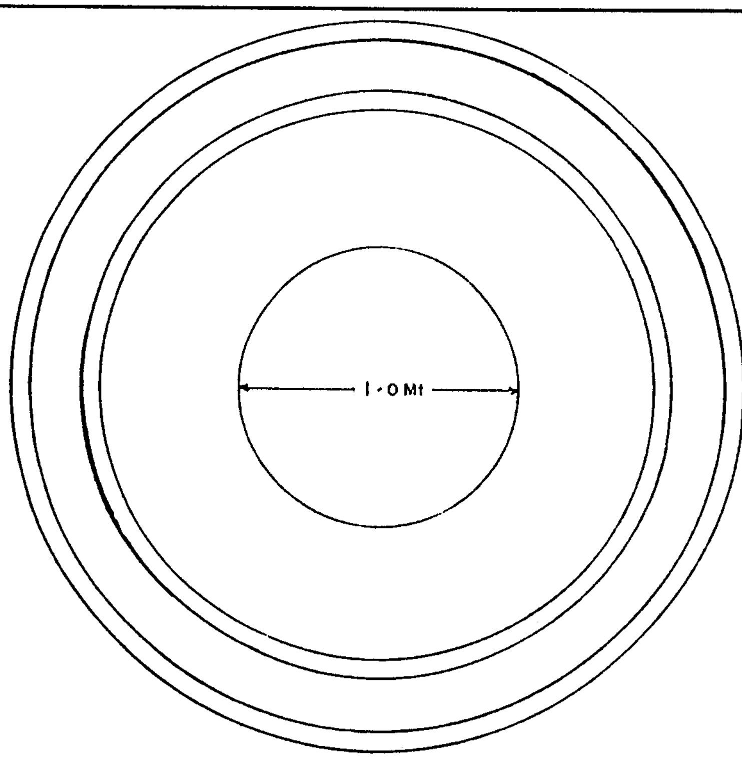
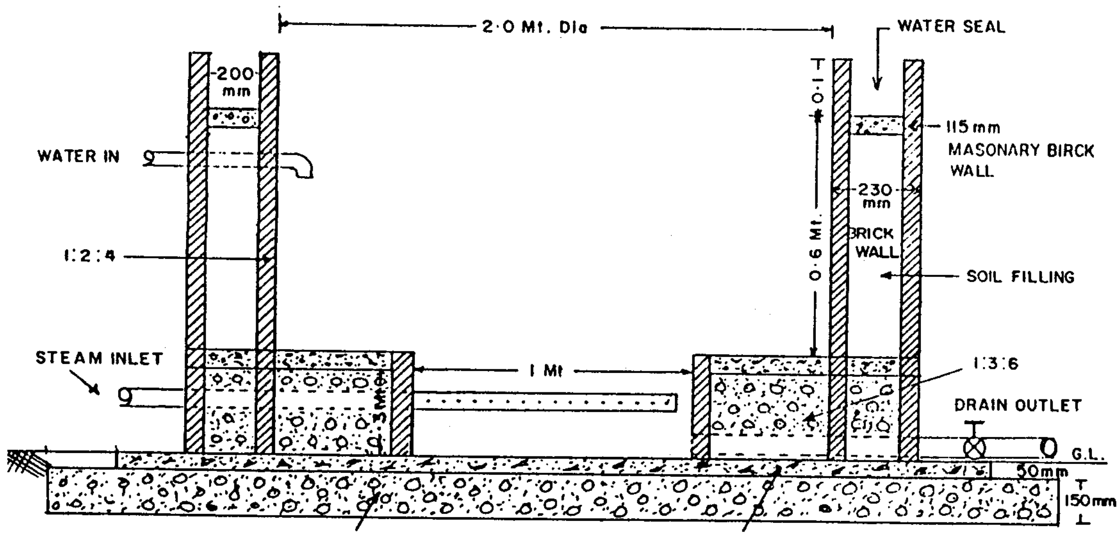


PLAN



CROSS SECTIONAL ELEVATION

Two types of micro-organisms namely aerobic and anaerobic play a key role in bio-pulping processes. Aerobic fungi such as species of Ph*anerochaete chrysosporium, aureobasidium Pullulans, Pleurotus spp., Ceriporiopsis subvermispora, Phellinus pini, Stereum hirsutum*, etc. are successfully attempted world over as a pretreatment in bio-pulping. The effect of fungal pretreatment resutls in decrease in refining energy requirement, reduction in cooking time and lower chemical requirement. Despite several advantages as reported above, the major technical problems encountered with bio-pulping are scale-up studies, maintenance of purtiy of the inoculated cultures, aeration and prevention of contamination by unwanted micro-organisms. Further production of fungal inoculum. sterilisation of raw material and environmental control during treatment pushes up the expenditure thereby making the process cost prohibitive.

Under such circumstances, the anaerobic micro-organisms which brings out the desired changes at room temperature standout as the best choice to be employed in the bio-pulping process. The pretreatment with the mixed microbial consortium under anaerobic environment brings about changes at a slower rate than aerobic micro-organisms but the conversion ot the material to the desired end product is uniform. This process can be a better alternative to the conventional chemical process and has great potential in the years to come under the changed global scenario.

A novel process of biological softening of cellulosic materials by anaerobic treatment has been developed and patented at CIRCOT, Mumbai[10]. The process has several advantages in terms of higher yield, better quality of pulp, process economy, environment friendliness, etc. and above all it is most practicable. The process involvēs pretreatment of chips with sodium hydroxide, followed by anaerobic treatment and a mild treatment with sodium hydroxide, washing of chips and mechanical refining to get pulp of desired quality.

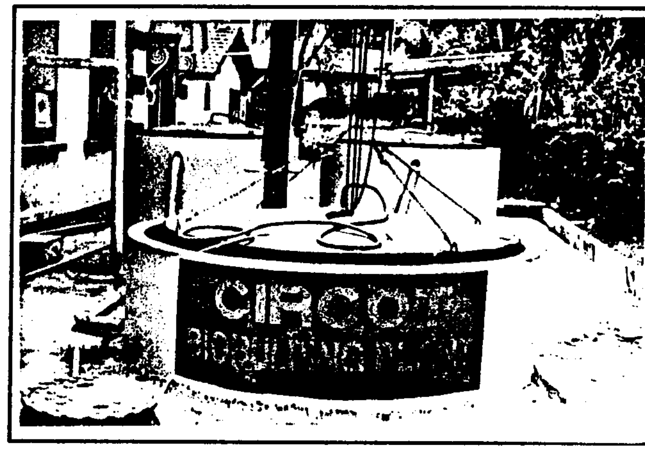
In this process, the complex microbial consortium under anaerobic environment, mediated by a systematic microbial succession, attack the lignocellulosic raw material to bring about the desired changes. The time of treatment can be altered by manipulating the concentration of alkali during the pretreatment of raw material. The size of the chips, concentration of the chemicals in the pretreatment decide the quality of the pulp obtained at the end of the treatment.

Even though the above process gave excellent results and indicated technical feasibility in the laboratory scale trials, it is highly essential that the process has to be evaluated at a pilot plant level before it is recommended for commercial exploitation. The present study, therefore is aimed at designing and developed to assess its technical feasibility and economic viability.

MATERIALS & METHOD

Experimental plant for processing 100 kg crop residues was set up at CIRCOT for undertaking pilot plant studies and evaluating economic feasibility. The drawing and photograph are given in Fig.1.

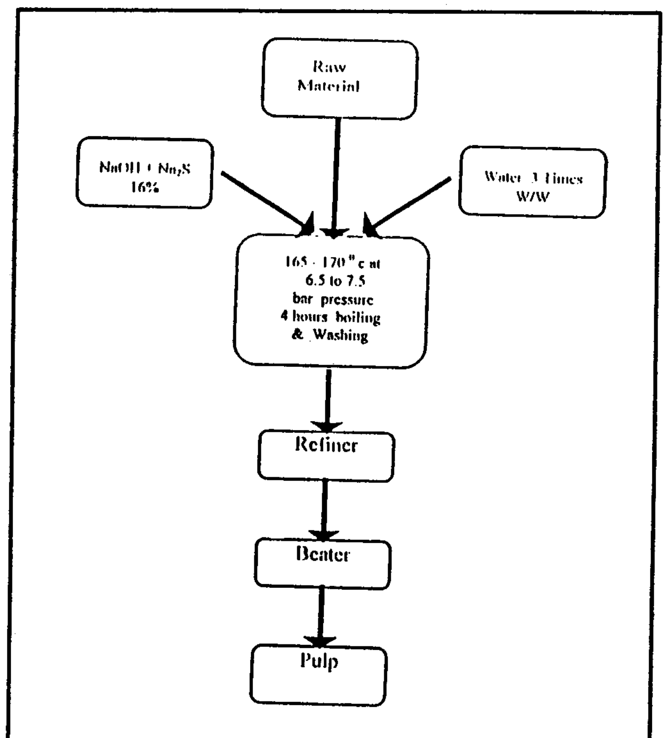
Fig.-1



The anerobic digester for preparing paper grade pulps designed keeping in view the requirement of its mechanical strength to hold the material, thermal insulation to avoid heat losses and leakproofness to achieve prefect anaerobic condition inside the plant. It is made suitable for operation even by unskilled labourer. It is simple brick masonary construction. The inlet and outlet pipes for steam are provided at the bottom. The substrate is isolated from steam pipes by providing a perforated steel plate. Water under this plate is directly heated by steam. A waterseal is provided on the top of digester to accommodate light weight

Fig.-2

Chemical Treatment Method



M.S. cover The M.S. cover has been given fibre glass coating on its inner as well as outer surfaces to prevent rusting. Chain pulley arrangement is provided over the plant for handling the cover and materials.

OPERATION & RESULTS

PROCESS

Flow diagram of the chemical process for preparation of pulp is given in Fig.2. Flow diagram of the anaerobic process for preparation of pulp is given in Fig.-3. It is observed that considerable saving in consumption of chemicals is achieved apart from saving in electrical energy and thermal energy.

OPERATION

The cotton stalks were soaked in alkali (4% w/w) in substrate to water ratio of 1:4 and heated at 100°C for 30 minutes by passing pressurised steam generated through a baby boiler. The water was drained and fresh water was added with 10% mixed microbial consortium as inoculum. Thereafter it was subjected to seven days of anaerobic treatment. CO_2 evolved during this 7 days was allowed to bubble out through a hose pipe dipped in water. Later, the water from the material was drained out to collect the inoculum for recycling in the fresh batch and the material was cooked for 30 minutes at 100°C in alkali (1% w/w). Thereafter, the material was passed through a refiner only in the case of cotton stalks before beating.

RESULT

The properties of the paper prepared from anaerobicaly treated pulp are on with the conventional chemically prepared pulp. The loss in strength has

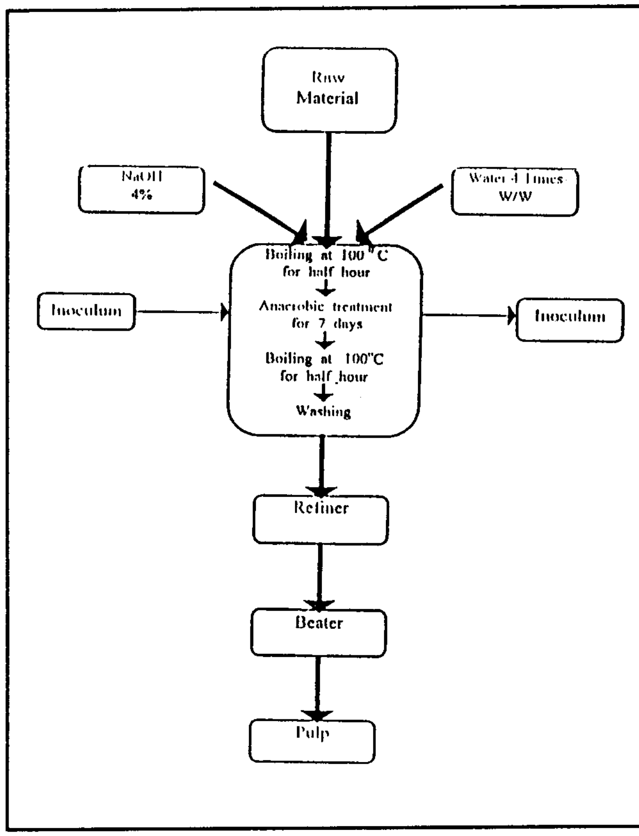
TABLE-1

Inputs for Anaerobic Digestion Method

1	Number of digesters	:	5-7 (Batch), 1 Semi-continuous
2	Captial cost	:	Rs. 1,25,000/-
3	Capacity of each digester	:	To digest 100 kg material at a time
4	Water requirement	:	400 litres
5	Requirement of chemicals	:	5% w/w of raw material (for hard material) or 2% w/w (for soft material)
6	Thermal condition	:	30 minutes heating of substrate before and after anaerobic digestion at 100°C
7	Electrial energy requirement	:	No stirring is needed

Fig.-3

Anaerobic Treatment Method



been regularly noticed in the biopulping method wherein basidiomycetous fungi are used for softening the pulp. However, the present anaerobic method not only retains the strength but can be increased by appropriate manipulations depending on the end uses (CIRCOT Patent -176891).

The chart in Table-1 shows details of construction cost for processing 100 kg raw material per day and corresponding daily running cost requirement. Saving in cost of chemicals, thermal energy, income generated and pay back period is shown in Table 2&3.

Based on these results, the corresponding consturuction costs and saving in chemicals, thermal energy and electrical energy are worked out for paper plants of different capacities for easy adoption of this anaerobic process partially or in full in place of chemical process. The data are given in Tables 4 to 8.

CONCLUSION

By adapting anaerobic treatment process in place of chemical and semichemical process for preparation of paper grade pulp, following benefits can be obtained.

TABLE-2

Energy Calculations For Rice Straw and Wheat Straw

I	Capacity of plant	Chemical pulping process (Enthalpy) Thermal energy requirement in MJ/day	Anaerobic process (Enthalpy) Thermal energy requirement in MJ/day	Energy saved per day in MJ	Money saved/day Rs.
A	100 kg	221.03	115.34	105.69	39.63
II	Capacity of plant	Chemical pulping process Electrical energy requirement for stirring in KWH/day	Anaerobic process Electrical energy requirement in KWH /day	Energy saved per day in KWH/day	Money saved/day Rs.
B	100kg	15	Nil	15	37.50
III	Capacity of plant	Chemical pulping process NaOH & Na_2S requirement	Anaerobic process Chemical requirement NaOH	Saving in use of chemicals	Money saved/day Rs.
C	100 kg	16 kg	2 kg	14kg	210.00

* For writing grade paper
Total (A)+(B)+(C) = Rs. 287.13
Saving per year = Rs. 100495.50
Pack back period = 1.75 years.

TABLE-3

Energy Calculations For Cotton Plant Stalks

	Capacity of plant	Chemical pulping process (Enthalpy) Thermal energy requirement in MJ/day	Anaerobic process (Enthalpy) Thermal energy requirement in MJ/day	Energy saved per day in MJ	Money saved/day Rs.
A	100 kg	221.03	115.34	105.69	39.63
	Capacity of plant	Chemical pulping process Electrical energy requirement for stirring in KWH/day	Anaerobic process Electrical energy requirement in KWH /day	Energy saved per day in KWH/day	Money saved/day Rs.
B	100kg	15	Nil	15	37.50
	Capacity of plant	Chemical pulping process NaOH & Na_2S requirement	Anaerobic process Chemical requirement NaOH	Saving in use of chemicals	Money saved/day Rs.
C	100 kg	16 kg	5 kg	11 kg	165.00

Total saving/day = A+B+C = Rs. 242.13/-

Saving/annum = Rs. 87,120/-

Pay back period = 2 years.

TABLE-4

Electrical Energy Consumption for Different Capacity Plants

No.	Capacity of plant in tonnes/day	Saving in electrical energy in MJ by adapting anaerobic treatment	Amount saved in Rs./day
1	10	2430	2430
2	20	4374	4374
3	30	4860	4860
4	40	5832	5832
5	50	7290	7290
6	100	14580	14580

TABLE-5

Thermal Energy Consumption for Different Capacity Plants

No	Capacity of plant in tonnes/day	Thermal energy required in MJ (Chemical Process)	Thermal energy required in MJ (Anaerobic Process)	Thermal energy saved in MJ	Amount saved in Rs./day
1	10	21103.712	11534.32	9569.392	3588
2	20	42207.424	23068.64	19138.784	7176
3	30	63311.136	34602.96	28708.176	10764
4	40	84414.858	46137.28	38277.568	14352
5	50	105518.56	5761.6	47846.96	17940
6	100	211037.12	115343.2	95693.92	35880

TABLE-6

Consumption of Chemicals for Different Capacity Plants

Capacity of plant in tonnes/day	Chemicals consumed in chemical pulping process (tonnes)	Chemicals consumed in anaerobic process (tonnes)	Saving in consumption of chemicals (tonnes)	Amount saved per day in Rupees
10	1.6	o.5	1.1	16,500
20	3.2	1.0	2.2	33,000
30	4.8	1.5	3.3	49,500
40	6.4	2.0	4.4	66,000
50	8.0	2.5	5.5	82,500
60	16.0	5.0	11.0	1,65,000

(1) **Considerable saving on energy during processing.**

(2) **Considerable reduction in the quantity of chemicals.**

TABLE-7

Statement of Total Saving in Rs./day

Capacity of Plant in tonnes/day	Saving in Thermal Energy in Rs./day	Saving in Electrical Energy in Rs./day	Saving in Chemical in Rs./day	Total saving per day in Rs./day
10	3588	2430	16,500	18,930
20	7176	4374	33,000	44,550
30	10764	4860	49,500	65,124
40	14352	5832	66,000	86,184
50	17940	7290	82,500	1,07,730
100	35880	14580	1,65,000	2,15,460

(3) The process is environment friendly

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TABLE-8

Capacity of plant (Tonnes)	Approx.Area occupied by Anaerobic Digester (in sq.mts)	Capital cost involved for changing over to Anaerobic process (in lakhs)	Saving per year (lakhs)
10	400	25	66
20	800	45	155
30	1200	60	227
40	1600	80	301
50	2500	110	377
100	5000	200	754

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