Increased Understanding of Bagasse Pulping for Improved Chemical Recovery Efficiency and Better Environment

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ABSTRACT

During the last decade fibrous raw material availability has been the major constraints confronting the paper industry During the endeavour for the search of alternative raw material bagasse has emerged as a potential fiber resource. Number of mills have started using bagasse in varying proportions in their raw material furnish. Although the pulping technology has been fairly well established but still there is necessity of increased understanding of the pulping process from the view point of chemical recovery operation and pollution aspects The present paper deals with the findings of the investigation of pulping variables on the black liquor properties and the pollution loads exerted. Effect of pith content which is carried along with fibers in varying proportion on the black liquor properties have also been investigated.

India is one of the largest sugar producing country in the world. About 2.5% of the land is utilized for sugarcane cultivation and over 180 million tonnes of sugarcane is harvested every year. It is estimated that the quantity of bagasse available is adequate for production of more than 3 million tonnes of paper per year. These figures support the fact that bagasse is going to be the main fibrous raw material for our pulp and paper industry in coming years. In the last decade bagasse has emerged as a potential fiber source for pulp and papermaking in India. Today, a number of mills are utilizing bagasse in varying proportions in their raw material furnish. Although pulping technology for production of chemical and newsprint grade pulps has been established, but still it is felt that there is a necessity of increased understanding of pulping of bagasse from the view point of chemical recovery operation and environmental aspects. For bagasse which has more open structure, vapour phase pulping involving cooking at low bath ratio, would be ideal. In the pilot plant studies conducted earlier[1], it has been shown that vapour phase pulping of rice straw was advantageous and it was indicated that energy requirement and pollution loads exerted were on lower side compared to conventional liquid phase. Continuous digesters are ideal for pulping of bagasse, but as small mills cannot afford to install them, there is a need to utilize existing batch digesters for vapour phase process. There is also a greater need for understanding the physico-chemical properties of black liquor from bagasse pulping. The mill samples tested in CPPRI laboratories showed abnormally high viscosities compared to the viscosity values reported by Kulkarni etal[2] for tropical hardwoods which are supposed to give black liquors with very high viscosites.

For smooth operation of chemical recovery units for treatment of bagasse black liquors it is essential to understand the factors that may be influencing the physico-chemical properties.

Pith content which is a contrary enters the digester in varying proportion depending upon the depithing efficiency. It has been reported that about 10% of pith is invariably carried over with fibers[3]. So it was decided to study the effect of the presence of pith along with fibres on the black liquor properties.

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RESULTS AND DISCUSSION

a) Vapour Phase Pulping :

It has been established that cooking at lower bath ratio using continuous digesters requires less steam and short cooking cycles, however investments in continuous digesters is high and possible only for mills with capacity greater than 150 tonnes per day[4]. Until economically suitable continuous digesters are developed, bagasse based mills may have to use existing conventional digesters with higher material to liquor ratio. Present studies on pilot plant scale were carried out to ascertain the possibility of carrying out pulping at low bath ratio (vapour phase).

Normally a high bath ratio is kept while pulping agricultural residues, as due to their bulky nature more liquor is required to Soak the material and as a result more requirement of steam and further increase in the bath ratio due to steam condensation takes place. This results in generation of large volumes of effluents of low solids content. It also results in reduced chemical concentration in digester thereby reducing effectivity of pulping. In vapour phase pulping process, the pulping is carried out at a reduced bath ratio of 1 : 3.5 by pre-soaking the raw material in cooking chemicals followed by pulping.

Pulp Properties :

The results of pilot plant scale pulping experiments are recorded in Table–1. It is noted that pulp yield in vapour phase pulping was 3 4% higher than liquid phase pulping with same amount of chemical charge. Keller[5] has also observed that the pulp yield increased with reduced material to liquor ratios. The reject content of vapour phase pulp was on lower side compared to the corresponding liquid phase pulp indicating uniform cooking in vapour phase process also. The fiber classification shows that the vapour phase pulps had relatively small proportion of —28 fraction indicating better fiber separation. The strength properties of vapour phase pulps were better. The vapour phase pulp had kappa number lower by 3 points indicating higher rate of delignification. The results indicate that better and uniform cooking occurs in vapour phase pulping along with yield advantage and improved strength properties.

Table–1

CHARACTERISTICS OF WHOLE BAGASSE PULPS (PLANT TRIALS)

Particulars	Liquid Phase	Vapour Phase
Pulp yield, %	37.6	41.0
Kuppa Number	28.3	24.9
Freeness, CSF ml	150	195
Tensile Index, N.m/g	51 5	54 0
Tear Index, m.N.m^2/g	4.40	4.70
Burst Index, k.Pa m^2/g	3.15	3.40

Energy Requirement : It has been reported that heat consumption of 60,000 k.cal/adt, at 1 : 4 bath ratio was drastically reduced to 10,000 k. cal/adt when material to liquor ratio was brought down to 1 : 3 1[6]. In the present studies from the mass balance it was found that steam consumption for liquid phase pulping was about 5.31 tonnes per tonne of pulp whereas for vapour phase process it was only 2.47 tonnes per tonne of pulp. Thus with lower materinl to liquor ratio there was considerable savings in steam consumption. Thus it is necessary to monitor carefully the material to liquor ratio from view point of economic usage of steam.

The black liquor solids concentration was more than double in vapour phase than in the liquid phase. The steam required for evaporating the two black liquors to 50% solids/tonne of pulp was calculated. With a steam econony of 1:3, less then half the quantity of steam will be required in vapour phase black liquor due to higher initial concentrations.

Characteristics of effluent generated : Tables 2 & 3 show that the volume of effluent generated in liquid phase pulping was much higher than in vapour phase pulping process. Increased volume of effluents is due to increased demand of water in washing stage. It was observed that based on conclusion, the vapour phase pulps required about 30m^3 of water during washing stage while the liquid phase pulps required about 47m^3 of water. Reduced quantity of water during washing stage is presumably due to easy removal of water soluble absorbed organics on the surface of the fiber. The total solids and COD load is also on lower side for vapour phase effiuent. The increased dissolved solids loads is attributed to lower pulp yield in liquid phase pulping. The increased COD load (40%) in liquid phase pulping effluents might be due to presence of more oxygen consuming organic compounds formed by degradation of lignin and carbohydrates.

Table–2

CHARACTERISTICS OF EFFLUENTS FROM PULPING OF WHOLE BAGASSE (PLANT TRIALS)

Particulars	Liquid Phase	Vapour Phase
Raw material, OD kg.	800	880
Chemical charge, %	17.2	17.5
NaOH concentraction, kg/m³	33 7	59.1
Cooking liquor, m³	4 0	2.5
Raw material to cooking liquor ratio Initial/Final*	1:5.1/1:7.1	1:3/1:4
Steam, tonnes/t of O.D. pulp	5.37	2.47
Black liquor, m³/t of O.D. pulp** including washings	23.5	9.8

* At the end of cooking

**Includes black liquor both free and concluded in pulp.

Cooking temp, 160°C, 60 min at 160°C

Table–3

CHARACTERISTICS OF EFFLUENTS FROM LABORATORY PULPING OF BAGASSE

Particulars	Whole Bagasse Vapour Phase	Whole Bagasse Liquid Phase	Bagasse fibres*	Pith Portion*
Pulp yield, %	55.9	55 2	58.9	50.4
Black liquor generated, m³/t	Nil*	7.8	7.85	11.9
Total dissolved solids, kg/m³	620	770	523**	797**
COD, kg/t	992	1694	647**	837**

* Black liquor was in occluded form

** In black liquor alone.

* Cooked in liquid phase.

Black Liquor Properties : Practically small volume of black liquor is generated in vapour phase pulping. But due to increased steam condensation, volume of black liquor generated in liquid phase pulping is on higher side. It was noted that black liquor had solid content of about 9% from vapour phase process as compared to liquid phase process (4%).

b) **Rheological Properties of bagasse black liquors :**

Mill samples of bagasse black liquors were studied for their rheological properties. Bagasse black liquors showed viscosity over 1000 m.Pa.Sec. at 58% solids and at 80°C. From the studies conducted at CPPRI on the black liquors from different raw materials it was shown that spent liquors from tropical hardwoods exihibit very high viscosities. But the bagasse black liquor showed viscosity almost 4 times more than the viscosity of black liquors from woods.

Detailed study was undertaken to understand the factors attributing to high viscosities of bagasse black liquors. From the studies it is revealed that the whole bagasse black liquors was colloidally unstable and was difficult to concentrate beyond 50% solids.

Viscosities were determined at a residual alkali of 1.9 gpl (as NaOH) and it was found that at this alkali level the liquor could not be concentrated beyond 45% solids (Table—4). However when the residual alkali

Table–4

VISCOSITY OF BAGASSE BLACK LIQUORS

B.L. sample	RAA g/l	Brockefield viscosity, mpa. Sec at 80°C at% solids 35	40	45	50	Swelling Volume Ratio, m'/g
Whole bagasse (Liquid Phase)	1.9	100	355	841	—	18
Whole bagasse (Liquid Phase)	6.2	42	79	119	562	15
Bagasse fibres (Liquid Phase)	4.5	53	211	1000	3162	21

level was raised to 6 2 gpl by addition of caustic improved fluidity was observed and concentration upto 50% solids was possible. It can therefore be inferred that a residual alkali level of 6–8 gpl as NaOH must be maintained in the black liquor for smooth operation of evaporators. Bagasse free from pith was relatively more stable colloidally but exhibited high viscosities. One of the reason attributed for high viscosity was the fact that bagasse black liquors contained higher proportion of high molecular weights lignin fractions. It was also noticed that these black liquors contained significant proportion of dissolved hemicelluloses presumably from the pith entering along with fibers. Pant etal[7] have reported that spent liquor from bagasse have a high to low molecular weight ratio of 1:2 48, which can be one reason for high viscosity of these liquors. The ratio is 1:4.47 for rice straw spent liquors. Bagasse spent liquors were reported to have about 3% hemicellulose and 3% hydroxy acid, which may also influence the viscocities.

It can thus be concluded that due to the presence of pith in the black liquor, there are possibilities of getting black liquors which are more colloidally unstable and are bifficult to concentrate.

Effect of Pith Content :

Most of the mills use depithed bagasse for pulping. However, some amount of pith is carried to the digester as not all pith is eliminated in depithing process. Ramalinga Setty, et al[3] have reported that about 9–10% of pith is carried to the digester along with fiber portion. Present studies were conducted to study the effect of pith on pulping with special emphasis on black liquor properties. In Table—2, yield obtained by vapour phase & liquid phase pulping of whole bagasse fibres & pith reveal that high yield of about 59% is obtained in case of pith free fibres. Under similar conditions yield is about 55% in liquid phase & 56% in vapour phase pulping process. Due to fibre being free from pith, total dissolved solids in black liquor from bagasse fibres is low at 523 kg/m³, & also is the COD load. Table–5 shows the strength properties of whole bagasse & pith free bagasse. It can be observed that strength properties are marginally higher for bagasse fibres. Pith has a distinct effect on drainage characteristics of pulps. Measured at 200 ml CSF, there is an apprcciably high rate of drainage for bagasse fibres pulp compared to whole bagasse pulp. Suspended solids in black liquor of whole bagasse are also higher.

TABLE—5

STRENGTH PROPERTIES OF BAGASSE PULPS (LABORATORY SAMPLES)

Pulp	CSF ml	Drainage time, sec.	Burst Index kpa.m²/g	Tensile Index N.m/g	Tear Index mN m²/g
Fibre	200	14.5	4,55	78.0	4 80
Portion	250	11.5	4 35	74.5	4.90
Whole	200	19.4	4.30	76.0	4.20
Bagasse	250	12.5	3 85	69.0	4.30

d) Recovery by Ferrite Process :

In coming years bagasse is likely to replace other agricultural residue like rice straw and wheat straw and small mills may start using bagasse in their raw material furnish in varying proportions. It has been well established that mills with capacity more than 30 t/d may not be economically viable in absence of chemical recovery system. CPPRI has developed an auto-causticising ferrite recovery and it has been established that it is suitable for small mills using non-woody raw materials[8]. This process was studied at Mandya National Paper Mills. The black liquor in the mill is concentrated to 40-45% solids. The black liquor properties are given in Table—6. The haematite ore used in the process was obtained from Bhadravati which contained about 90% Fe_2O_3 Batch trials involving combustion of thick black liquor with ferric exide in roaster were coducted. The objective was to find out the response of haematite ore and condition of roaster (temperature profile, reducing atmosphere, etc) towards auto-causticization. The results are given in Table—7. In batch experiments the causticizing efficiency of the haematite ore varied from 53 to 84%. During experiments visually it was observed that the temperature of the roaster was not constant which resulted in varying degree of causticization. The particle size of the ore also play an important part in causticizing efficiency. It was found that-200 mesh size particles is optimum. However with - 40 mesh particles also, high causticizing efficiency. It was found that viscosity changes after addition of haematite ore to black liquors of 50% solids (58.3% solids after addit on of haematite ore) were not appreciable and viscosity did not rise abnormally. The results indicate that ferrite process can be applied to bagasse liquor and high recovery efficiency can be achieved.

TABLE—6

CHEMICAL COMPOSITION OF BAGASSE BLACK LIQUOR (MILL SAMPLE) USED FOR FERRITE PROCESS

Particulars	Weak Black Liquor	Thick Black Liquor
Total solids, % W/w	3.50	39 33
Sp. Gravity (30°C)	1.014	1.232
Inorganics, % as NaOH	31.60	28 67
Silica as SiO_2, g/1	6.57	—
Residual alkali, g/1	2.00	—

TABLE—7

RESULTS OF AUTO-CAUSTICIZATION IN BATCH SCALE EXPERIMENTS AT MNPM, BELAGULA

Black liquer solids to Ore ratio	Causticity,%	Observation
1:1.13	56.8	Product was soft brownish
1:1.13	76.8	Roaster temperature was higher and was red hot.
1:1.13	72.2	—do—
1:1.28	60 1	(–20) mesh ore
1:1 28	82.3	(–40) mesh ore

EXPERIMENTAL

Raw Material : For laboratory studies, bagasse bales were procured from M/s. Mandya National Paper Mills Ltd, Belagula (Karnataka). The bales were broken manually into small pieces. Part of this material was dipithed by first soaking in water for overnight and than passing through Sprout Waldron disc refiner at very high clearance so that pith was loosened and no damage was done to the fibres. Pith was separated by screening on Serla flat screen. Both pith and fibres were dried. For pilot plant trials whole bagasse was collected from nearby sugar mills.

Laboratory Pulping Experiments : Initially it was studied as to how much material to liquor ratios should be maintained in vapour phase pulping. Due to bulky nature of bagasse, it was found that a bath ratio of 1:3.5 was required to completely soak the raw material. The conventional liquid phase pulping was carried out in series digester consisting of six bombs each of 2.51 capacity, heated in polyethylene glycol electrically. Material to liquor ratio of 1:7 was maintained. After cooking the liquor was squeezed out through nylon cloth, and the pulp was washed with warm water after disintegrating for 5 minutes. In vapour phase pulping the raw material was soaked in cooking chemical (NaOH solution) at a material to liquor ratio of 1:3 5, which was then charged to the autoclaves and cooked. No additional liquor or water was added. The pulp was disintegrated and washed with warm water.

Pilot Plant Scale Experiments : Liquid and vapour phase pulping experiments on whole bagasse were carried out on pilot plant scale. The raw material was charged to the 11 m³ tumbling digester and cooking liquor from liquor preparation tank was sprayed from the top of the digester. Addition of raw material and cooking liquor was done alternating to each other to have uniform liquor absorption. In vapour phase pulping process initial bath ratio of 1:3 was kept and in liquid phase pulping it was 1:5. After cooking, the pulp was blown into the blow tank. Blow tank consistency was determined to find out the steam condensation. It was also checked from the recorder of steam input line. Pulp was them washed and screened.

Ferrite Recovery Experiments : Ferrite recovery experiments were conducted in Mandya National paper Mills. The thick black liquor with known amount of sodium was taken and it was calculated on ignition how much of sodium carbonate will be generated. Varying quantities of powdered haematite ore (Fe_2O_3) were added. The black liquor haematite mixture was kept in a bag and wrapped in paper and finally kept in a wire cage which was hung in the oil fired rotary kiln for 15 minutes. The product (sodium ferrite) was powered and hydrolysed in boiling water for 15 minutes and filtered. The causticity of the cooking liquor generated was determined.

Physics Chemical Properties of spent liquors :

Viscosities of the black liquors were determined at varying solid contents as per method described in the manual of Laboratory Research method. The swelling volume ratios of the black liquor were determined by the method of Oye[9] etal also described in the lab manual[10].

Measurement of Pollution Load :

Dissolved solids and chemical oxygen demand (COD) was determined in black liquor (effluent samples). The method employed for COD determination was as per described in 'Waste Water Analysis'—a Course Manual of National Environmental Engineering Research Institute, Nagpur.

Spent Liquor Analysis :

The analysis was carried out according to procedure described in Tappi Standard Method T-625-to-64.

Pulp Evaluation :

Pulp Evaluation and paper testing were carried out according to the procedure based on the standard methods given in laboratory manual[10].

CONCLUSION

1. Vapour Phase Pulping has distinct advantages over conventional liquid phase pulping.

— It requires about 50% less steam for pulping operation;

— Produces about 50% less effluents :

— Water consumption is reduced substantially;

— Increased pulp yield is obtained without sacrificing the strength properties;

— Black liquor with more than double the concentration compared to liquid phase black liquors are produced, which in turn require less steam for concentration during chemical recovery operation.

2. The pith has a sizable influence over pulp and on black liquor properties. Due to presence of pith in bagasse, colloidally unstable black liquor will be generated.
3. To have colloidally stable black liquors a residual alkali level of 6–8 gms per litre is desirable.
4. Mill and lab black liquors showed colloidal unstability, tendency of precipitate and high viscosity which can be attributed to the presence of high molecular weight lignins, hemicellulose fractions and organic acids.
5. Trials of ferrite process developed for treatment of non-weedy raw materials gave encouraging results on plants scale.

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