Conservation of bagasse-during storage

RANGAN S. G.*

ABSTRACT

World over cane crushing season varies from 3 to 11 months; whereas the pulp mill requires continuous supply of bagasse throughout the year. This means bagasse *has got to be stored* at least 6—7 months per year.

Fresh undegraded bagasse gives the best results in pulping. Loss and deterioration of bagasse during storage is high.

Bagasse being a bulky low density material, must either be baled in high dense stacks to facilitate storage and handling and also to reduce area of storage.

Therefore a need for proper method of storing for conservation of bagasse fiber has become incresingly apparent. This paper discusses in detail the present practices of storage available, their merits and demerits.

Factors for selection of storage method

It is necessary that bagasse is either baled in dense bales or piled in high dense stacks in order to facilitate storage and handling and to reduce the area of storage. Other factors to be considered in deciding upon storage method are—

a) handling of high volumes in relatively short working periods—necessity for employing a large labour force.

b) necessity for storage and preservation under uniform conditions to keep fiber losses low and to maintain uniform quality.

c) necessity for removing and handling the fiber as quickly as it is produced by the sugar factory so as not to interrupt the sugar mill operations.

d) eliminating fire hazard and insurance costs.

e) eliminating the danger of lung disease

f) high cost of wire and problem of wire removal

g) distance of pulp mill from sugar mill

h) whether bagasse can be stored at sugar mill or must be handled either to pulp mill or to another location for storage

i) labour cost and labour availability in the area

j) comparative cost between manual handling and mechanical handling

k) length of sugarcane crushing season

l) rain fall in the area

In the view of Taiwan Sugar Corporation technologists, quality of pulp manufactured from bagasse after storage is much better and consumption of chemicals is less also than that manufactured from green bagasse.

It is preferable to let all the bagasse to be stored before feeding to pulping process.

But Dr. Cusi contradicts this with the following statement :

Fresh undegradnd bagasse gives the best results in pulping (i.e.) stronger pulp and higher yield

The notion that stored or aged bagasse is better for pulping is based more on the inability of the equipment and processes used presently for coping with handling problems.

Losses in storage

Losses vary considerably depending on the following two methods of accounting—

a) moisture free

b) moisture and water solubles free

*Adviser,
Seshasayee Paper & Boards Ltd.,
MADRAS.

As fermentation loss itself is 5%–6%, total loss of 10% is good and 15% is acceptable.

Deterioration of Bagasse during storage

Bagasse is bio-degradable. After sugar extraction, the condition of bagasse is ideal for *moulds*, *yeasts* and *bacteria* to multiply. The rate of degradation depends on temperature, amount of nutrients, pH, the degree of aerobicity.

At the beginning of fermentation yeasts consume the sugar within 5 days. A rapid multiplication of bacteria takes place and these attack bacteria of middle lamella and fungi cellulose.

The degradation of bagasse fiber occurs at the end of fermentarion mainly due to an increase in *actinomycetes* and *fungi* which attack all components of fibers namely hemicellulose and lignin.

Factors influencing bagasse losses in storage

Together with the micro organism, the factors that contribute to material losses are air, temperature, sun light, rain, wind and mechancical handling in depithing, transporting stacking and reclaiming.

a) **Sun** Radiation has a negligible effect except on the piles surface.

b **Wind** increases heat dissipation and tends to oxygenate the surface layers of the piles.

c) **Rain** cools the pile by absorbing heat. Rain penetration is usually small and has little influence on the piles' internal conditions.

There is a school of thought that after good depithing. the hazard of fermentation is negligible or totally removed as sugar juice carrying capillary and pith cells are nearby located. This theory has not been borne out by facts. During the harsh crushing and depithing operations, the mechanical impact causes the impingement of a number of thermophillic bacteria and a range of fungi on the exterior of the cane.

	Fiber	Pith
% Sucrose	5.582	5.414
% Invert	1.094	1.130

Distribution of nutrient remains percentagewise the same in the fiber after extraction of pith.

Bio-Chemical reactions during storage

The chemical compositions and reactions of various products involved in bagasse storage as well as corresponding heat generation are given in Tables 1 & 2. In actual practice, all the mentioned reactions take place at once; the rate of each depending on many factors :

1 The invert sugars (glucose & fructose) already present in fresh bagasse are oxidised to alcohol and CO_2 and contribute more in the initial acceleration of micro organism and heat generation (Reaction 2).

2 The same micro organisms hydrolyse the sucrose to glucose and fructose again.

3 Energy liberated appears in the form of heat.

4 The increase of temperature inhibits the growth of Saccharomyces. Lactobacilli may proliferate at 50°C and produce lactic acid. (Reaction 5). Unless the environment is also at a low pH, thermophillic organisms also develop.

5 In presence of O_2 more and more heat is released glucose and fructose may get oxidised to CO_2 rather than to Ethanol and CO_2 (Reaction 4).

6 Predominant bio-chemical reactions are splitting sugars into ethanol and CO_2 and in presence of atmospheric O_2 acetic acid is also formed (Reaction 6).

7 For optimum conservation of cellulosic content of bagasse, it is necessary that bio-chemical reactions should be selective in the sense only the soluble organic matter should be involved.

Effect of temperature of Pile on Microbial activities

At 18–20°C, most active micro organisms are fungi and yeasts which feed mainly on soluble sugars.

In aerobic conditions, sugars are oxidised to water and CO_2. As the environment becomes anerobic more and more due to piling of fresh bagasse over the hydrolysed sugar, they get split into ethanol and CO_2. This reaction will reduce—

a) the availability of sugars

b) increase the temperature

c) increase microbial population.

Stage 2 : At temperature above 22°C activity for

TABLE—1

Compound	Formula	Molecular Weight	Heat of Combustion Cal/Gr. Mol	K. Cal/kg.
Sucrose	$C_{12}H_{22}G_{11}$	342.3	1348.2	3939
Glucose & Fructose	$C_6H_{12}O_6$	180.16	669.94	3719
Ethanol	C_2H_5OH	46.07	326.68	7091
Acetic Acid	CH_3COOH	60.05	209.02	3481
Lactic Acid	$CH_3CH(OH)COOH$	90.08	326.8	3628
Pure Cellulose	$(C_6H_{10}O_5)n$			4600

TABLE—2

CHEMICAL REACTIONS AND HEAT GENERATION

	Reaction	Heat Generation Cal/Gr Mol of Sucrose
1	$C_{12}H_{22}O_{11}$ (Sucrose) + H_2O ———→ $2(C_6H_{12}O_6)$ (Glucose & Fructose) +	8.32
2	$2(C_6H_{12}O_6)$ (Glucose & Fructose) ———→ $4(C_2H_5OH)$ (Ethanol) + $4CO_2$ +	33.16
3	$C_{12}H_{22}O_{11}$ (Sucrose) + $12O_2$ ———→ $12(CO_2)$ + $11(H_2O)$ +	1348.2
4	$2(C_6H_{12}O_6)$ (Glucose & Fructose) + $6O_2$ ——→ $6CO_2$ + $6H_2O$ +	1339.88
5	$2(C_6H_{12}O_6)$ (Glucose & Fructose) ——→ $4(CH_3CH(OH)COOH)$ (Lactic Acid) +	32.68
6	$4(C_2H_5OH)$ (Ethanol) + $4O_2$ ———→ $4(CH_3COOH)$ (Acetic Acid) + $4H_2O$ +	470.64

yeasts decreases and other mesophillic organisms that use sugar as primary nutrient appear.

Stage 3 : At about 40°C, thermophiles take over.

Stage 4 : Pile temperature increases to maximum level of the tolerance of thermophiles.

Summing up, below 30°C no damage happens. Cellulose attack begins as temperature rises above 30°C.

If enough soluble nutrients are available and temperature is 50°C, thermophillic organisms that will predominate are lactic acid producing bacelli. By their action, pH decreases and retards the cellulolytic micro organism from growing.

On the other hand, if nutrients are insufficient, the microbial action takes a different course and if pH is not lowered, cellulosic material may become damaged.

Most favourable temperature for Lactobacilli is 50°C. Most favourable temperature for Cellulolytic organism is 55°C. Hence *key factor* in determining the course of microbial evolution in a pile *is the pH*.

Methods of storing bagasse

Various methods for storage of bagasse have been practised. they are classified as follows :

1 **Bale storage method**
   a) Celotex method
   b) Thibodaux method
   c) Taiwan method
   d) Large bale storage method

2 **Dry bulk storage**
   a) The Tablopan method—Venezuela
   b) The standard building products method—Jamica

3 **Wet bu.k storage—Ritter's Process**

4 **Moist bulk storage**
   a) Valentine method
   b) Moist bulk storage after compaction

5 Begatex–20 Process

1 Bale storage methods

Celotex Method

This method was developed by the Celotex Corporation for baling, storage and preservation of bagasse. Long ago this method was considered to be good and was in wide use for more than 45 years. In this system the bales are picked up with heavy duty cranes and deposited on a pile where labourers stack the bales in place and put a metal roof over the pile.

Air passages between adjoining bales should be unobstructed to get maximum cooling effect by natural air draft or wind.

For achieving effective cooling, piles should not be very large, the air passages must be free of loose material and the bales should not exceed certain transversal dimensions. Otherwise their centre may remain for a longer time at high temperature and may become degraded.

Thibodaux Method

When supply of labour becomes difficult and costly, a completely mechanical system for handling bagasse bales was developed in Lousianna by Thibodaux Baler Company. In addition to saving of labour costs, this handling resulted in losses and better stacking. Bale weight—125kg.

The Taiwan method

Taiwan sugar corporation and Taiwan Pulp and Paper Corporation jointly developed a system of making small bales of 25-30kg. This is basically meant for areas where labour is cheap. A bucket type of stacker capable of moving on rails can stack these bales on storage area.

Large bale storage

In order to reduce handling and transport costs to a minimum, bagasse is moist depithed well in sugar mills and compacted into large bales (800 kg). These are mechanically loaded on trailers and transported to storage area. Loss is reported to be lower and there is lot of saving in handling costs.

2 Dry Bulk storage

Tablopan dry storage system in Venezuela

Bagasse after camplete depithing, is passed through two disk refiners and then through a rotary drier where it is dried to 90% dryness. The dry fiber is hydraulically pressed into large mats of 200 kg/m^3 and stored.

Standard Building Products Ltd. Method

This method is practised in Jamaica. This is same as in Venezuela except that dried bagasse is briquetted and pelletised (300–400 kg/m^3).

	Method of storage	Advantages	Disadvantages
1	**Bale storage method**	Transport cost is lower particularly from Sugar mills located beyond 100 km (e.g. Sancristobal Mills Mexico)	a) Fire hazard of dry bagasse in storage is extremely great. b) Loss and deterioration of dry bagasse in storage are veryhigh. c) Area needed is large relatively. d) Application of mechanical devices for piling the bales is limited. e) Operation is labour-oriented.
2	**Dry bulk storage**	Losses are minimum	Drying is a costly process in countries where energy is purchased at high cost.
3	**Wet bulk storage**	a) Fire hazard is almost not there. b) Loss and deterioration is less. c) Area needed for storage is much less. d) Fully mechanised handling devices can be adopted with less labour. e) Quality of bagasse being better-results in less chemical consumption.	The operation and maintenance of the slurry pumps and pipelines for wet piling are always troubled with problems such as wear, cloging, etc. If these pipelines are replaced by *overhead open channels* made of wood built along the centre line of the yard and let the bagasse to get dropped to storage slabs through chutes after the bagasse and bio liquor gets mixed in the channel during travel. a) Storage field construction is costly. Equipment involved is also costly. b) Bagasse remains at a very low pH—3.5-4. All equipment handling this bagasse must be of SS construction. c) BOD of waste effluent is excessively high unless all the water is recirculated. d) High consumption of water and power.
4	**Moist bulk storage**	Saving in power and water compared to wet bulk storage systems.	a) Losses are high. b) Bagasse fiber is relatively degraded.
5	**Begatex Process**	a) Transport cost will be lower. b) Colour and properties of fiber are maintained for atleast 24 months. c) Acclaimed as best-for Preservation Method.	Microbial fluid is still kept as a secret and is a monopoly product.

3 Wet Bulk storage

Ritter's Process involves impregnating the bagasse with a biological liquor and flushing the suspension in a bulk storage area through elevated channels. The addition of a small amount of molasses to the initial culture solution provides biological liquor for treatment of incoming bagasse. Acid medium and anaerobic conditions combine to provide an environment which will prevent the development of undesirable micro-organisms and thereby facilitating the storage of bagasse over long periods with a minimum fiber loss.

In 1956 Ngoye Paper Mill in Felixhu Zululand S.A., the largest Ritter Plant to be built to date for storage of bagasse was put into operation at the Ladesma Mill in Argentina in 1964.

The biological liquor consists of lactic acid bacteria which can be reproduced by adding certain quantities of molasses to the biological liquor.

Description

The technical process is divided into two circulation systems.

Primary circulations system is used during crushing season. The partially depithed or undepithed bagasse is conveyed from the sugar mill to an elevated channel where it is mixed with biological liquor from the stabilisation tank and flushed to a large slab of reinforced concrete forming part of storage area. Bagasse forms a 3-4% suspension in the channel with bio-liquor. A number of parallel channels traverse the storage area. These are covered with wooden boards with perforations which permit the excess liquor to be drained off. This can be recirculated to stabilisation tank.

The bagasse stored forms a large pyramid and soon forms a compact pile into sides inclining at 45° angle. The normal stacking height for mills of large production capacity is 20-30 metres.

The bagasse retained on the storage absorbs 50% of the bio-liquor used. Therefore, fresh water and bio liquor make up is necessary before recirculation. 0.25% of fresh biological culture solution has to be added to the amount of liquor in circulation per minute.

Secondary Circulation System comes in to operation for reclaiming stored bagasse from the pile during the off season. The wooden covers are removed from the transverse channels and raw water or pulp mill back water is passed through these channels. Bagasse is reclaimed from the pile and flushed via transverse channels to the bagasse tank. From this tank this bagasse slurry is pumped to a dewatering device and dewatered bagasse is conveyed to pulp mill. Large quantities of water obtained during dewatering process are passed over a screen to separate pith and then recirculated.

Effect of storage Conditions on Fiber Quality in Ritter Process

Humidity : As storage time increases, the maximum humidity content of the pile moves towards the inside of the pile. If residual humidity of the pile is low then the lactic acid bacteria cannot survive leading to degradation of fibers. pH increases and undesirable microbia contaminates are produced. Humidity percentage should be kept very high.

pH : Average pH values lie between 3.5-3.8.

Rainfall : Heavy rainfall has no effect on the stack. Even daily showers upto 300mm did not have any negative effect on the quality of stored bagasse because of rapid regenerative powers of biological celline. Rain cannot penetrate the stack and only top layer is affected.

Bagasse Fiber quality changes during and after storage in Ritter Process

Physical characteristics

1 Colour : Fresh bagasse fiber has a clear yellow colour before storage. It also contains 3% loose pith. The rest of the pith sticks to the fiber. In stored fiber, change in colour is observed. Stored bagasse darkens slowly in aerobic environment and by the action of light, darkening is accelerated. In case of improperly stored bagasse, substantial changes occur in colour indicating uncontrolled fermentation which may change the light brown fibers to reddish and dark brown fibers.

This fiber will consume more alkali and pulp mill vary in properties. Yield will be lower.

2 **Amount of loose pith** after storage operation increased upto 10%.

3 **Dirt content** of stored bagasse is low. This is due to dilutions and dewatering operations involved.

Changes in chemical characteristics

Cold and hot water solubles decrease from 11% to 3.5% after 90 days storage.

1% caustic solubility of inside layer decreases and remains constant after 6 months storage. % lignin, pentosans and Holo cellulose contents of fiber increased in proportion to reduction of solubles. Differences in chemical characteristics between fresh and four months stored bagasse fiber is given below :

	Fresh bagasse	Stored bagasse
Alcohol-Benzene solubles	8 25	1 77
Cold and Hot water solubles	2.58	1.78
1% NaOH solubility	30.31	22.72
Lignin content	19.36	21.47
Pentosans content	29.06	30.84
Holocellulose content	69.55	74 76

Losses in the Ritter storage system

At Ledesma, Argentina, it was found that the total weight loss at the Ritter Storage is 10%. Out of this 10% loss, 7% loss is due to the decrease in water and alcohol-Benzene solubles. The remaining 3% represnts physical fiber losses in material handling process. An additional 10%weight loss is indicated at the dewatering operation by the separation of pith.

Effect of storage on Pulp quality

Investigations on the effect of storage of bagasse on pulp quality were made at Ledesma Mill, Argentina. These are reported in the Literature[5]. These are shown in the following table :

Effect of storage of bagasse on the Pulp Quality

			Fresh bagasse	Stored bagasse
1	Caustic Soda consumption in digester	%	13.1	11.6
2	Digestion yield	%	52.8	53.0
3	Screening Reject	%	8.1	4.0
4	Kappa Number		16.4	14.7
5	Freeness of Unbleached pulp		620	665
6	Weak black liquor solids concentration	%	5.8	7.2
7	Caustic Soda Recovery	%	77.9	82.2
8	Freeness of Bleached pulp		570	630
9	Dirt content (PPM)		14.8	13.3
10	Bleachcd pulp strength at 600 CSF			
	—a) Tensile (M)		4843	5282
	—b) Tear		58.9	62 3
	—c) Burst Factor		36.8	35.0

According to the studies made, the Caustic soda consumption in cooking of stored bagasse is lower than cooking of fresh bagasse. This is due to lower quantities of Caustic Soda and Alcohol-Benzene solubles present in the stored fiber. Lower pith content in the stored fiber is also a reason for lower consumption of alkali.

The cooking yield of both fresh and stored fiber remained same. But the fresh fiber pulp contained a considerable amount of uncooked fiber bundles whereas in the stored fiber, no uncooked fibers were observed. This has increased the screen rejects.

Pulp freeness of stored bagasse was higher than fresh bagasse. This is due to the lower pith content of the stored bagasse. Stored bagasse consumed less water in the brown stock washing operation than fresh bagasse. Less foaming problems were observed using stored bagasse.

The weak black likquor concentration was higher in stored bagasse due to lower amount of water usage during the washing operation. Soda loss is higher in the case of fresh bagasse due to poor washing operation.

The strength properties like tear and tensile were higher for stored bagasse due to the lower amount of fines present in the pulp.

Advantage of Ritter Process

a) The bagasse conservation is perfect.

b) Handling and transport costs are less.

c) Compaction is good at 225 kg/m^3.

d) Cost of biological fluid is low.

e) Pith, ashes, coal particles and sand are eliminated.

f) Fire danger completely disappears as bagasse always saturated with biological liquid thus saving in insurance expenses.

The International Paper Company's Process

Loose bagasse from the sugar mills is suspended in water and pumped to storage area at 2.5% consistency. Once the pile is started, it is shaped by bull-dozers and heavy duty front end loaders. Without biological treatment it was necessary to keep sprinkling the bagasse with water throughout the storage period so that the material can be kept wet to its full water holding capacity (above 85% moisture).

Water cannot be recirculated without creating an odour which will continue to huild up. Therefore water will have to be used only once, then allowing this water to drain off.

Cusi Process

A modified Ritter's process is suggested by Dr Cusi. Only yeast is allowed to react with residual sugar in bagasse to produce ethanol and carbon dioxide. The heat generated is taken away by circulating cold air in the system.

Methods for Bagasse Conservation

Dr. Cusi suggests two methods—

a) by use of inhibitors such as air drying processes and bactericides such as SO_2, formaldehyde, sodium carbonate etc in a bagasse pile.

b) by preventing the growth of non-cellulolytic micro organisms that will retard or prevent the proliferation.

The first method is very effective but very costly in actual practice.

The second method can be carried out in two ways :

a) By promoting the predominace of mesophillic, non-cellulytic micro-organisms.

b) By promoting the predominance mesophillic non-cellulolytic micro-organisms.

Conservation by promoting the growth of acid producing bacteria–Lactobacilli

Spontaneous fermentation starts at ambient temperature and releases heat that raises the pile's temperature to over 50°C. Under such anaerobic conditions, Lactic acid producing bacteria prevail over other streams by lowering the pH of the material to about 3.4. This retards deterioration by slowing down the growth rate of cellulolytic or other undesirable micro organisms.

If this method has to be successful, certain conditions are to be maintained precisely :

a) Sufficient quantities of sugar and other nutrients should be available in bagasse. This can be met by adding nutrients such as molasses and aluminium compounds, phosphates, etc.

b) The pile should be anaerobic. Pile should be very compact.

c) pH of pile should be low. For this Lactobacilli should be inoculated. This bacteria would react with sugar to produce lactic acid which keeps the pH low.

d) The material should have enough moisture to allow propagation of life.

Conservation by promoting the predominance of mesophilic non-cellulolytic micro organisms

This method preserves bagasse by controlling flow of air through the pile to create a controlled temperature environment for mesophillic type bacteria *like yeast* which consumes and exhausts the soluble nutrients present in the material. The growth of other micro organisms that degrade the fibers is retarded by reducing the moisture content of material to well below 28%.

Conditions to be maintained

a) Heat dissipation to be more than heat generation. Pile should be cooled with air.

b) Nutrient content should be low in the pile.

4 Moist bulk storage systems

The valentine pulp and paper company has developed a storage system in which freshly milled bagasse is conveyed by belt conveyor from sugar mill to storage area where it drops on to a rotating belt type stacking conveyor and is stacked in one large circular pile. The outside layer of this pile gets damaged but then forms a protective shell for material below which is under anaerobic condition. This prevents the destructive fermentation and heat build up which occurs in bale storage.

Philippines Method

Loose bagasse is spread evenly over the storage area by means of bull-dozers and at the same time bull-dozers compacted the bagasse layer to a density of 350 kg/m^3.

5 **Begatex—20 Process**

Usina Santa Lydia based Ribeirao Preto, Sao Paolo Brazil is using this unique process.

It involves rapid drying of bagasse in 600-900 kg bales, down from 50 to 20% moisture content or even less using a biochemical catalyst which accelerates but carefully controls the micro biological fermentation of residual sugars in bagasse.

To preserve the fiber properties and to reduce storage losses, one of the following two conditions must exist during the storage period :

a) Bagasse moisture content must be below 20% so that micro organism which damage the cellulose fibers cannot live.

b) The bagasse must be kept wet throughout and until its water holding capacity is reached which is at about 80% moisture content.

Bagasse treated by this system (Begatex—20) can be stored for more than 2 years without fiber deterioration or serious losses. The bagasse has a far higher fuel value than raw bagasse.

The trend for several years in bagasse storage has been towards wet bulk storage with the best method being the Ritter Biological Pre-treatment method which provides controlled fermentation under unaerobic conditions. These methods result in excellent preservation of bagasse and low loss in storage. Therefore for most grades of paper and board, except newsprint where sugar mill is almost always built adjacent to the pulp mill, it is likely there would be no advantage of the Begatex-20 process as compared to wet bulk storage.

Actual mechanism of the Process

A combination gives catalytic action of a biochemical fluid mixed into the bagasse and the dense bale appears to create favourable conditions for the development of certain micro organisms already present in the bagasse. This accelerates an exothermic reaction involving fermentation of residual sugar, gums, waxes, etc.

The biochemical catalyst controls the fermentation so that there is first a gradual temperature increase by the action of mesophilic microbes which are most active at lower temperatures. As the temperature rises and pH decreases, the activity of the thermophillic microbes which are already present in the bagasse, is stimulated, greatly accelerating the exothermic fermentation reaction. During this period there is competition for food and the mesophilic microbes are killed because the thermophillic ones are more active.

During the Thermophillic stage, temperature increases rapidly with further lowering of pH. By the time the maximum temperature and minimum pH are reached on about the 10th day, the food is exhausted and most of the thermophillic microbes also die. Even those which survive initially show extremely low activity at low moisture content and eventually die.

During the fermentation also, about the 10th day, the temperature reaches 60-70°C in the case of the bales and the pH drops from 7 to 2.8 or 3.0 as a result of acids formed.

As the temperature rises, moisture is expelled rapidly from the bagasse through capillary and is usually down to 28-30% by the 10th day. The high temperature reached remains stable for an additional 10 days or more and by the 20th day, the moisture content has been reduced to 20% or less.

Main advantages in manufacture of Newsprint by mechanical pulping

Fresh bagasse from sugar mill has a brightness of 40-50°GE. When bagasse becomes dark after fermentation, the brightness goes down to 20°GE or even beolw.

Peroxide or Na-hydro sulphite can bring about a maximum of 20° brightness only. This means if stored bagasse has a low 20° GE brightness, the bleached mechanical pulp from this bagasse can be max 40°GE only which is not adequate for newsprint.

Bagatex process can maintain the colour of bagasse at 35-40°GE level and with the help of peroxide, this can be bleached to 55-60°GE brightness.

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