# DETERIORATION OF BAGASSE DURING STORAGE AND ITS PREVENTION*

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RESUMO

*Foi realizado um amplo estudo para pesquisar as causas da destruição microbiológica de bagassos, determinar a influência dos diferentes parâmetros e para verificar a possibilidade de proteção com preservativos químicos. Este trabalho foi elaborado parte em uma fábrica de aglomerados em Trinidad e parte no laboratório.*

*Este parecer fornece informações sobre os microorganismos os quais foram encontrados durante a armazenagem dos bagassos. Inicialmente o açúcar restante é consumido através de levedura em seguida bactérias atacam, principalmente a pectina na lamela média e também atacam a hemicelulose. A eles seguem-se fungos, os quais atacam tanto a hemicelulose como a celulose e lignina. No total foram testadas 33 substâncias com diferentes concentrações. Mais efetivas foram as ligações orgânicas de enxofre.*

*Para preservação de chapas pode-se afirmar que diversos produtos deram efeitos sem que a qualidade das chapas fosse alterada. Porém são necessárias concentrações mais elevadas que para os bagassos.*

## 1. BAGASSE AS FIBRE RAW MATERIAL.

The total anual production of sugarcane amounts to about 690 mill. to (FAO 1976) leading after extraction of the juice to 150 mil of fresh bagasse. Os this less than 10% are utilized as fibrous raw material for pulp as well as fibre-and particleboard. The major part is burned in the boilers of the sugar mills for energy production.

At present around 30 medium-sized pulp mills (100 — 250 to) and about 50 smaller ones (less than 30 to) with a total capacity of 1.3 mill to pulp per year exist. In addition more than 20 plants are producing around 280.000[3] particle board per year. (FAO 1975).

Thus bagasse has to be considered as a promising source for additional fibrous material. Whereas the technology of the production processes is fairly well established, one serious limitation is the possible deterioration of bagasse during storage.

## 2. DETERIORATION OF BAGASSE DURING STORAGE

Sugarcane is a yearly crop and can be harvested in most regions during a period of 5 — 7 months, in Central America for example from December until June, in South Brazil from June till December, and in Louisiana/USA only from October — December.

For a continuous supply of bagasse to the processing plants it has to be stored for a considerable time. Due to its chemical composition bagasse is much liable to attack by microorganisms. A mature cane stem consists of about 73% water, 26% organic substances, of which 13% is sucrose and of 1% minerals. (DILLEWIJN 1952). After removal of the sugar juice by roller mills or diffusers bagasse contains about 50% water, 45% cell wall substance, 5% watersoluble substances, mainly sugar (PATURAU 1969) with a pH between 5.5 .. 6.4.

During storage fermentation of the residual sugar occurs rapidly producing an increase of temperature and a subsequent attack by thermophilic microorganisms; this leads to a lysis of the cellwalls, especially the middle lamella with a subsequent easier separation of the cells and to a cellwall degradation causing a reduced quality of the products and losses of raw material. Of special importance is also the "bagassosis" due to the inhalation of spores from **Ther-**

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**moactinomycetes sacchari** and **T. vulgaris** leading to a chronic irritation of the respiratory systems with sometimes severe consequences.

For the storage of bagasse several methods have been developed which reduce microbial deterioration by controlling fermentation, drying or reduced availability of oxygen (see WALTER 1978).

However, considerable difficulties still exist. In order to achieve a better protection of the stored bagasse a comprehensive study was undertaken for analysing the causes of the microbiological deterioration, the influence of various parameters and for applying chemical measures. The work was done partly at a particleboard plant on Trinidad, partly in the laboratory (WALTER 1978). In the following some of the results are presented.

## 3. MICROORGANISMS IN STORED BAGASSE.

For understanding the deterioration process in stored bagasse, its microbial flora was analysed at different times and the enzymatic activities investigated.

### 3.1 Conditions in bagasse piles.

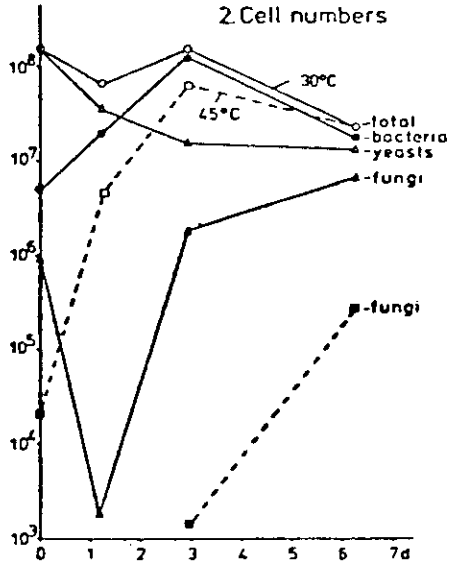
The temperature changes rapidly in bagasse piles with a certain fluctuation; for example in a pile of 9 m height from about 30° to 40° (1 d), to 55° (2 d), 60° (20 d) and to 62° (27 d). Another pile of 15 m showed an increase to 84°C after 6 weeks and to 75° after 12 weeks. The pH decreased from about 6 to 2 — 2,5, the moisture content in the center of the piles remained fairly constant (between 110% and 120%). The bagasse material changed its color to light-brown (6 weeks) resp. dark brown (12 weeks) and became loose and brittle.

A similar development also occured in a pile simulator with an inner size of 100 x 100 x 250 cm, where 300 kg fresh bagasse were observed regarding pH moisture content and temperature.

### 3.2 Microorganisms in stored bagasse.

In order to analyse the microorganisms present and to study their succession a small thermoincubator was used with a content of 3.5 l, sufficient for 500 g of fresh bagasse. The progress of fermentation was measured by means of the temperature increase and corroborated by $CO_2$ analyses. Samples were taken from fresh bagasse after one, three and six days of storage (details see SCHMIDT and WALTER, 1978).

Per gram of dry bagasse up to 2 x 10 8 living microorganisms cells were counted. (Fig. 1)



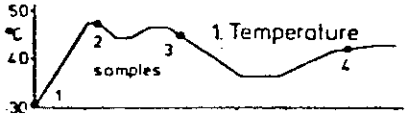




**Fig. 1** Development of temperature in fermenting bagasse with the four points of taking samples (1.) and succession of microorganisms during fermentation (2.). *Unbroken lines* represent mesophilic microorganisms resulting from the 30°C isolation. *Broken lines* show the thermotolerant species after 45°C isolation temperature (O. Schmidt, Walter, 1978)

From agar plates at 30° and 45°C altogether 400 pure cultures were isolated, of which 110 were further identified. They consisted of 82 bacteria, 7 actinomycetes, 14 yeasts and 7 fungi. The yeasts consist mainly of **Candida guilliermondii, Kluyvernomyces cicerosporus, K. marxianus, Rhodotorula glutinis and Saccharomyces capensis.** They dominate in the early fermentation, followed by bacteria (rods, cocci, bacilli), actinomycetes and fungi. From the latter **Absidia corymbifera, Chrysosporium, Keratinophyllum, Paecilomyces variotii** and **Phialophora lignicola** were identified.

### 3.3 Enzyme activities.

The enzyme activities of the bacteria, yeasts, actinomycetes and fungi were tested with sucrose, pectin, xylan, cellulose, and for phenoloxidase ('lignin').

From the 82 bacterial strains 24 could utilize sucrose, 18 pectin, 43 xylan and 4 cellulose. All 14 yeasts did use sucrose, but none of the other components, 4 of the 7 actinomycetes degraded xylan and cellulose with one strain exhibiting phenoloxidase; most of the fungi did utilize xylan and cellulose, with **Chrysosporium keratinophyllum** and a fungus imperfectus as phenoloxidase positive. The results are presented in table 1 for the bacteria and yeasts and in table 2 for some actomycetes and fungi.

Regarding the succession of these microorganisms it can be stated that at first the residual sugar is consumed preferable by the yeasts most of it already within the first day, than the bacteria attack predominantly the pectin of the middle-lamella and the hemicelluloses, followed by fungi which utilize the hemicelluloses, cellulose and also the lignin. Thus, a deterioration of the cell wall with a loss of substance and strenght can begin after only one week storage.

These observations and conclusions were confirmed by investigating naturally stored bagasse after 6 — 9 months. Of the isolated micro-organisms (n = 70) 71% were bacteria, mainly bacilli, and the remaining actinomycetes, yeasts and fungi. The enzymic results are similar to those from the latter stage of the controlled fermentation above.

## 4. PREVENTION OF DECAY

For the prevention of microbial deterioration several storage methods have been developed, like biological ones (Ritter process) due to souring by Lactobacillaceae, chemical treatment with propionic acid or storage in dry condition as bales or briquettes. Practical experience, however, shows that a considerable decay still occurs, so that the application of preservatives appears necessary.

Altogether 33 preservative substances were tested at different concentrations in a pile-simulator containing 500 g of fresh bagasse. As an indicator for the toxicity against the microflora the temperature was measured; a constancy of the initial temperature indicates no activity, because no energy is released due to consumption of material, whilst a modification of the temperature curve typical for fresh bagasse indicates beginning effectivity of the preservative (Fig. 2). Most effective were organic sulfuric compounds (0,2%, 0,4%), boric acid was not toxic enough and propionic acid showed a beginning effectivity only at 1,6%.

Pentachlorphenolate and its sodium salt were only moderately effective.

According to calculations for wood chips a chemical conservation appears economical if it does not cost more than 50% of the possible loss of material (SMITH, HATTON 1971). A cost analysis for practical conditions on the basis of a storage of 15.000 tons of dry bagasse, 120 days harvest and 250 days of production for three common methods of storage reveiled, that application of preservatives for DM 50, — per ton of dry bagasse would still be economical. According to the results obtained a protection could be achieved for DM 30, — per ton of dry bagasse, so that a chemical treatment appears economical.

## 5. PROTECTION OF BOARD PRODUCTS

A further advantage of such preservation is to be seen in the protection against moulds of the boards produced of this bagasse. Since sugarcane is growing moistly in humid regions, the panel pro-

Table. 1 Distribution of bacteria and yeasts in the progress of fermentation (samples 1—4) with regard to their enzymic abilities

| Organism | sample | number of investigated strains | degradation of sucrose | | pectin | | xylan | | cellulose | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | np | %p | np | %p | np | %p | np | %p |
| bacteria and yeasts | 1—4 | 96 | 38 | 40 | 18 | 19 | 43[x] | 52 | 4 | 4 |
| bacteria | 1—4 | 82 | 24 | 29 | 18 | 22 | 43 | 52 | 4 | 5 |
| | 1 | 21 | 10 | 48 | 7 | 33 | 10 | 48 | 0 | 0 |
| | 2 | 20 | 6 | 30 | 4 | 20 | 13 | 65 | 0 | 0 |
| | 3 | 22 | 7 | 32 | 6 | 27 | 13 | 59 | 3 | 14 |
| | 4 | 19 | 1 | 5 | 1 | 5 | 7 | 37 | 1 | 5 |
| rods | 1—4 | 50 | 19 | 38 | 13 | 26 | 31 | 62 | 2 | 4 |
| | 1 | 9 | 7 | 78 | 5 | 56 | 7 | 78 | 0 | 0 |
| | 2 | 14 | 6 | 43 | 4 | 29 | 11 | 79 | 0 | 0 |
| | 3 | 15 | 6 | 40 | 4 | 27 | 10 | 67 | 1 | 7 |
| | 4 | 12 | 0 | 0 | 0 | 0 | 3 | 25 | 1 | 8 |
| cocci | 1—4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bacilli | 1—4 | 28 | 5 | 18 | 5 | 18 | 12 | 67 | 2 | 11 |
| | 1 | 9 | 3 | 33 | 2 | 22 | 3 | 33 | 0 | 0 |
| | 2 | 6 | 0 | 0 | 0 | 0 | 2 | 33 | 0 | 0 |
| | 3 | 6 | 1 | 17 | 2 | 33 | 3 | 50 | 2 | 33 |
| | 4 | 7 | 1 | 14 | 1 | 14 | 4 | 57 | 0 | 0 |
| yeasts | 1—4 | 14 | 14 | 100 | 0 | 0 | nt | | 0 | 0 |
| | 1 | 5 | 5 | 100 | 0 | 0 | nt | | 0 | 0 |
| | 2 | 2 | 2 | 100 | 0 | 0 | nt | | 0 | 0 |
| | 3 | 4 | 4 | 100 | 0 | 0 | nt | | 0 | 0 |
| | 4 | 3 | 3 | 100 | 0 | 0 | nt | | 0 | 0 |

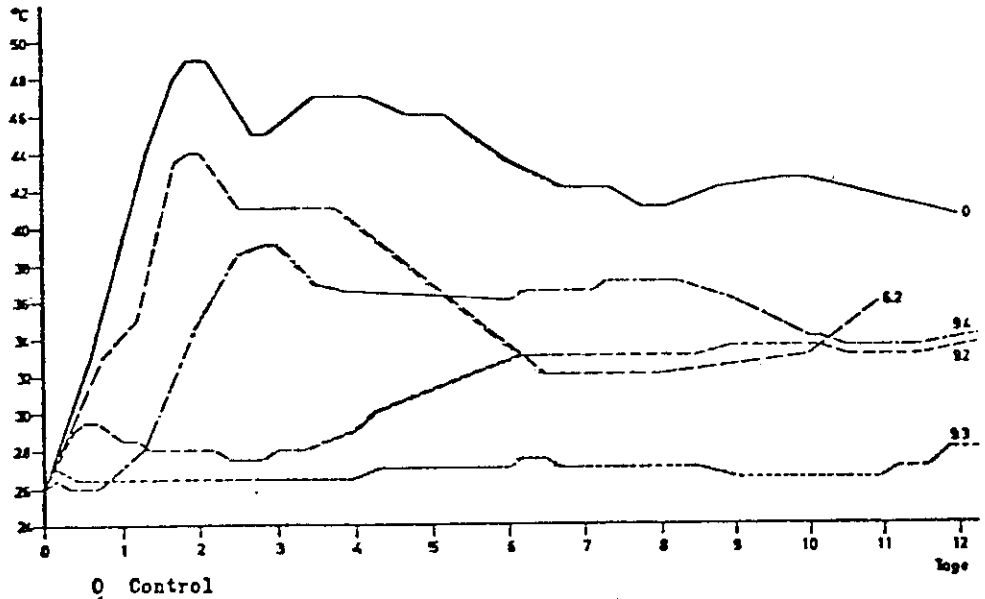
np = number of positive strains %p = percentage of positive strains x = 82 investigated strains
nt = not tested

Table.2 Occurrence of enzymes within some actinomycetes and fungi

| Strain | sample | max. cell number per g dry bagasse | degradation of xylan | degradation of cellulose | 'lignin' |
|---|---|---|---|---|---|
| actinomycetes | | | | | |
| 16 | 4 | $2 \times 10^5$ | + | + | (+) |
| 55 | 4 | $1 \times 10^6$ | — | — | ? |
| 57 | 1,4 | $2 \times 10^5$ | + | + | ? |
| 58 | 2,4 | $2 \times 10^5$ | — | — | ? |
| 59 | 4 | $1 \times 10^6$ | + | — | ? |
| 98 | 4 | $4 \times 10^5$ | — | (+) | nt |
| 99 | 2,3 | $1 \times 10^3$ | + | + | nt |
| fungi | | | | | |
| *Absidia corymbifera* (Cohn) Sacc. et Trotter | 4 | $1 \times 10^5$ | + | — | — |
| *Chrysosporium keratinophilum* (Frey) Carmichael | 3,4 | $1 \times 10^6$ | + | + | + |
| Fungus imperfectus 15 | 3 | $1 \times 10^3$ | + | — | (+) |
| Fungus imperfectus 19 | 3 | $1 \times 10^6$ | nt | + | — |
| Fungus imperfectus 20 | 3,4 | $1 \times 10^6$ | + | + | + |
| *Paecilomyces variotii* Bainier | 3 | $1 \times 10^3$ | + | + | ? |
| *Phialophora lignicola* (Nannf. apud Melin et Nannf.) Goid | 1,3,4, | $1 \times 10^3$ | nt | + | — |

+ = strong activity (+) = sparse activity — = no activity ? = no clear reaction due to pigment excretion nt = not tested ( O. Schmidt, Walter, 1978)

Fig. 2: Temperature tests with a preservative




0 Control
6.2, 9.2, 9.4 concentration not toxic enough
9.3 toxic concentration

ducts used there often are infected by moulds, leading to an unpleasant appearance, or even by wood destroying fungi. Therefore a surface treatment or protection of the whole boards is sometimes necessary.

To be effective also for the protection of the boards toxicants used for the storage of bagasse must be stable during the production process and not influence the gluing or reduce the quality of the board.

Therefore 19 of the chemicals tested above and others were investigated regarding their suitability for preventing fungal attack of the boards. Furthermore board-samples of 400 x 400 x 19 mm were prepared with urea resin glue mixed with the preservative and tested regarding their bending strenght and internal bond as well as mould resistance.

The results indicate that 5 preparations are effective in preventing mould without reducing the quality of the boards. They were also suitable for the storage of bagasse. However, higher concentrations are necessary for the protection of boards than for bagasse.

Finally it should be emphasized that by applying preservatives for the storage of bagasse and the protection of the boards the possible influences on the environment have also to be considered.

## 6. SUMARY

A comprehensive study was undertaken for analysing the causes of the microbiological deterioration of bagasse, the influence of various parameters and for applying chemical measures. Partly the work was done at a particleboard plant in Trinidad, partly, in the laboratory.

The paper informs about microorganisms found during storage. It was stated that at first the residual sugar is consumed preferable by yeasts, than bacteria attack predominantly the pectin of the middle-lamella und the hemicellulose, followed by fungi which utilize the hemicellulose, cellulose and also lignin.

To prevent decay of bagasse, altogether 33 preservative substances were tested at different concentrations. Most effective were organic sulfuric compounds.

For the protection of board products it was shown that several preparations were effective in preventing mould without reducing the quality of the boards, however, higher concentrations are necessary than for pure bagasse.

## 7. LITERATURE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