# REFINED SUGAR STORAGE TRIALS USING VARIOUS TYPES OF 25 kg PAPER BAGS

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**Abstract**

Refined sugar from each of four refineries was packed into several different types of 25 kg paper bags. Pallets of each type were stored at the coast at Maydon Wharf, where humidities are high, and inland at Bloemfontein, where humidities are low. These pallets were stored for one year during which time, temperature and humidity were monitored at each warehouse and the sugar was sampled and inspected for caking at three-monthly intervals. It was found that the permeability of the paper bag to moisture, coupled with the temperature and humidity conditions in the warehouse, had a significant effect on the quality of the stored sugars.

## Introduction

For many years the sugar industry has experienced complaints due to the caking of refined sugar in paper bags. As a result, a detailed study was made of the problem, its occurrence and causes. The objectives of the project were to survey the conditions under which refined sugar is stored in South Africa and to compare the keeping qualities of refined sugar stored in 25 kg paper bags with respect to changes in colour, reducing sugars and moisture content (caking potential). Sugar from selected refineries was stored for an extended period at different warehouses with varying ambient conditions. In addition a number of different packaging materials were compared.

Although six different refineries (Malelane, Pongola, Umfolozi, Gledhow, Noodsberg and Huletts) participated in the tests[1] and trial bags were stored at each of these refineries, only those refineries that sent sugar to Maydon Wharf and Bloemfontein will be considered in this paper.

## Participating Refineries

*Malelane (ML)*

Sugar manufactured at ML is passed through a Weibull conditioning silo before being packed. While in the silo the sugar is recycled for an average period of 48 hours. The silo has the facility to apply conditioned air but this is not often used. Sugar is bagged from the silo and packing temperatures of about 30°C are maintained, while the moisture content is kept as low as 0,02% (oven moisture)

*Umfolozi (UF)*

Umfolozi sugar is screened after the driers so that only particles greater than 0,5 mm and less than 1,8 mm are packed. Because of the effective cooler in the drier as well as the time taken to sieve the sugar, the average packing temperature is as low as 28°C.

*Noodsberg (NB)*

At the beginning of 1984 there were many complaints of NB sugar become sticky and wet. Packing temperatures at NB range from 35 to 45°C.

*-Hulett Refineries (HULREF)*

The average storage period at HULREF is 3 months and no caking problems have been experienced at their warehouse. Packing temperatures range from 40 to 45°C.

## Storage Venues

*C.G. Smith No. 8 Store, Maydon Wharf (MW)*

A number of refineries send their sugar to Maydon Wharf for storage prior to dispatch to other destinations. After monitoring the temperature and humidity in this store over a period of weeks during January and February 1984, it was noted that humidities reached 100% on some days. This store was therefore selected for its high humidity conditions and small temperature differences.

*Cordiner's Warehousing, Bloemfontein (BL)*

After discussions with South African Sugar Distributors (SASD) it became apparent that severe caking problems were experienced from time to time in Bloemfontein. This warehouse in Bloemfontein was chosen because of its expected low humidities and large temperature differences.

## Types of Packaging Used

All the bags used in these trials were filled through a spout which was not glued or sealed in any way.

*Three-ply paper bags*

These consist of three layers of brown kraft and are currently the most widely used bags throughout the industry. Sugar from each of the four refineries was packed into 3-ply bags.

*Four-ply paper bags*

These are made up of four paper layers and were used by refineries until recently when one layer was dropped to reduce the packaging costs. ML however has continued to use this bag. UF, ML and NB sugar was compared in these bags.

*Three-ply polylined bags*

These have three layers of paper and one free layer of polythene film one away from the sugar in the bag. ML, UF and NB filled polylined bags for these tests.

*Three-ply and four-ply polycoated bags*

These are in use at HULREF for export refined sugar and have the layer of paper one away from the sugar laminated with a polycoating. The polycoated layer does not provide a complete barrier against moisture since in the process of lamination paper fibres can stick out through the coating thus creating areas where moisture can pass through. The polycoated bags were compared using HULREF sugar.

## Storage and Sampling Procedure

At each refinery sugar was packed into each of three types of bags and distributed to both MW and BL. The pallets

were stored with the test pallet at the bottom and two other pallets on top of it for weight. The top pallet was used as a replacement pallet. The bags on the test pallet and replacement pallet contained the same sugar packed in identical bags.

At three-monthly intervals the test pallet was dismantled layer by layer and a bag was removed from each of the top, middle and bottom layers of the pallet. The pallet was then carefully repacked and a marked replacement bag was placed in the position from where the sample bag had been removed. The bag was marked to ensure that only original test bags would be sampled during future tests. The sampled bags were cut open, the sugar photographed and a sample taken for moisture, colour and reducing sugars determination. Thermohygrographs where installed at both warehouses to monitor continuously the ambient temperature and humidity conditions to which the test bags were exposed.

## Analytical Methods

Moisture, reducing sugars and colour determinations were performed according to the methods described in the Laboratory Manual for South African Sugar Factories.[2] Moistures were determined by the oven drying method because the total moisture determination is time consuming and it was felt that for the purpose of comparison surface moisture would be sufficient. Conglomerate counts were done on a sample of well mixed sugar. A slide was prepared and counted on a Kontron crystal analyser. In evaluating the crystals, twinned crystals, clusters, star shapes and occluded crystals were taken as conglomerates.

## Results and Discussion

### *Temperature and humidity records*

Small differences between maximum and minimum temperatures may indicate a well insulated store or actual small differences in outside ambient temperatures. Figure 1 shows that average weekly temperatures at both BL and MW are very similar from September to January after which BL temperatures decrease to values considerably lower than those at MW.

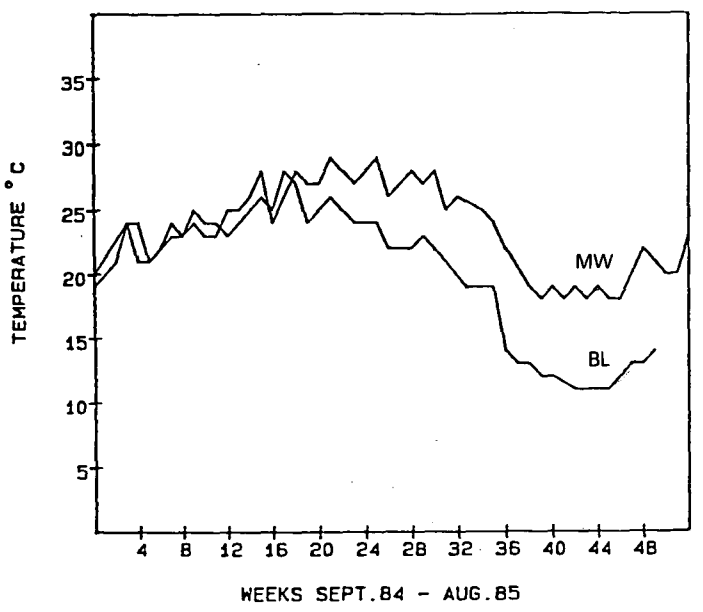


**FIGURE 1** Comparison of Bloemfontein and Maydon Wharf mean-temperatures

At both BL and MW the mean daily temperature difference was 3°C with actual maximum and minimum temperatures of 30°C and 8°C and 32°C and 14°C at BL and MW respectively. It is well known that in winter, outside ambient temperatures in Bloemfontein reach well below 5°C indicating that the BL store was well insulated against temperature changes. At MW however the sugar was stored in a warehouse where insulation was poor. Since the sugar, although under cover, was stored very close to a door which was kept open most of the time, the conditions that the sugar was subjected to at MW would have been similar to outside ambient conditions. Thus in the case of MW the small differences observed between day and night temperatures do not indicate a good store but rather mild ambient weather conditions. Since temperature changes would play an important role in causing caking in polylined bags it is important to have cycling between maximum and minimum temperature as low as possible.

Figure 2 shows that average weekly relative humidities at MW are above 70% most of the year. Since this is higher than the equilibrium relative humidity (ERH), ie the relative humidity above which sugar will absorb moisture from the atmosphere, the possibility of moisture being absorbed by sugar stored in paper bags at MW is significant.

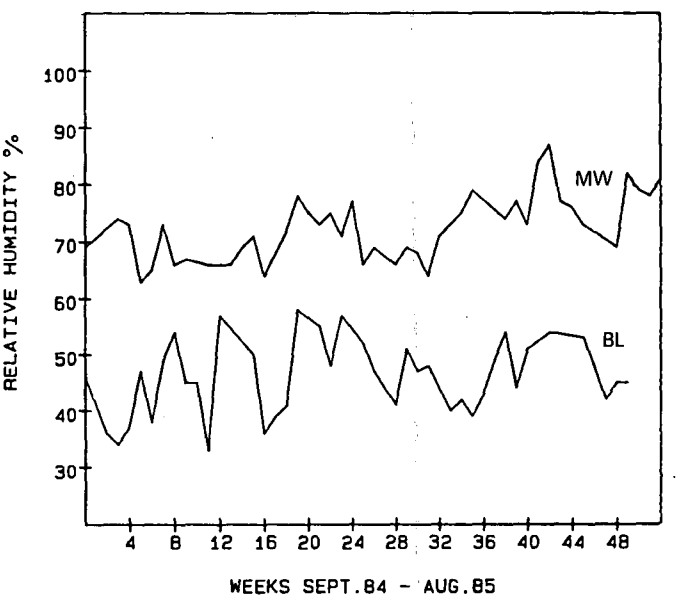


**FIGURE 2** Comparison of Bloemfontein and Maydon Wharf mean-relative humidities

Relative humidities at BL are mostly lower than the ERH of the sugar (Figure 2) and thus we can predict a drying out process to occur in this warehouse. Actual maximum and minimum relative humidities reached during the test period were 73% and 23% at BL and 100% and 31% at MW with mean daily differences being 7% and 9% respectively.

### *Moisture changes during storage*

Initially there was a general loss of moisture at both venues ie at the 2 month (November) sampling. This could have been due to a natural curing or conditioning which all freshly manufactured sugar undergoes as moisture trapped on the surface of the crystal is slowly released to the atmosphere. In the case of plain paper bags (Table 1) this moisture passes into the surrounding atmosphere.

TABLE 1

**Changes in moisture content of sugar during storage in 3-ply paper bags**

| | ML | NB | UF | HULREF |
|---|---|---|---|---|
| Packing | | | | |
| Temperature (°C) | 31 | 36 | 28 | 47 |
| Conglomerate (%) | 60 | 89 | 63 | 84 |
| Initial $H_2O$ (%) | 0,011 | 0,071 | 0,034 | 0,025 |
| **Moisture % at BL** | | | | |
| After | | | | |
| 2 months | 0,010 | 0,017 | 0,017 | 0,011 |
| 9 months | 0,009 | 0,007 | 0,012 | 0,011 |
| 12 months | 0,007 | 0,015 | 0,012 | 0,015 |
| **Moisture % at MW** | | | | |
| After | | | | |
| 2 months | 0,009 | 0,022 | 0,019 | 0,012 |
| 9 months | 0,010 | 0,530 | 0,015 | 0,010 |
| 12 months | 0,010 | 0,313 | 0,020 | 0,021 |

In the polylined bags (Table 2) however this would not be possible and some moisture is absorbed by the paper in contact with the sugar whereas the rest remains free to migrate within the body of the sugar in the bag.

TABLE 2

**Changes in moisture content of sugar during storage in polylined bags**

| | ML | NB | UF | HULFREF* |
|---|---|---|---|---|
| Initial $H_2O$ (%) | 0,015 | 0,065 | 0,035 | 0,023 |
| **Moisture % at BL** | | | | |
| After | | | | |
| 2 months | 0,009 | 0,020 | 0,017 | 0,010 |
| 6 months | 0,007 | 0,013 | 0,013 | 0,017 |
| 9 months | 0,008 | 0,004 | 0,012 | 0,009 |
| 12 months | 0,006 | 0,014 | 0,015 | 0,016 |
| **Moisture % at MW** | | | | |
| After | | | | |
| 2 months | 0,008 | 0,052 | 0,020 | 0,014 |
| 6 months | 0,004 | 0,027 | 0,014 | 0,009 |
| 9 months | 0,011 | 0,139 | 0,019 | 0,013 |
| 12 months | 0,008 | 0,167 | 0,021 | 0,022 |

* HULREF sugar was packed in polycoated bags.

Tables 1 and 2 show that with the exception of NB sugar the moisture content remained reasonably stable throughout after the initial drop. The moisture content of NB sugar remained stable at BL in both 3-ply and polylined bags whereas at MW an increase was experienced over the storage period. The increase was not as great in the polylined bags as in the 3-ply bags.

*Inspection at 2 months*

NB sugar became damp and sticky in the polylined bags at both venues. At MW all the sugar in the 3-ply and 4-ply bags caked while the sugar in the polylined and polycoated bags remained free flowing. There was no caking at BL after two months since moisture probably moved out of the bag due to the low ambient relative humidity.

*Inspection at 9 months*

At MW the most severe caking was observed at the 9 month inspection, ie in May. At BL however no caking was observed and only some small damp pellets were observed in the NB polylined bag. At MW all the sugar in the 3-ply and 4-ply bags had caked. NB sugar at MW had absorbed so much moisture that the sugar in the 3-ply and 4-ply bags as well as the poly bags was now wet and sticky. The HULREF sugar at MW was caked in the 3-ply bags, less caked in the 3-ply polycoated bags and still less in the 4-ply polycoated bags. The sugar in the polylined bags remained free flowing.

*Inspection at 12 months*

This final inspection took place in August after some rains had already occurred and the humidities had risen. Generally the caking observed was not as severe as it had been in May during the low humidity period.

There was no caking at BL and even the NB sugar in the polylined bag had dried out. This may be due to movement of moisture through the spout. At MW there was some caking in the 3-ply bags of HULREF and ML and none in UF sugar while NB sugar at MW was still wet and sticky.

*Changes in colour and reducing sugars content*

Table 3 shows the overall changes in colour and reducing sugars content.

TABLE 3

**Changes in colour and reducing sugars content over 12 months**

| | ML | NB | UF | HULREF |
|---|---|---|---|---|
| **Colour, ICUMSA 420** | | | | |
| At bagging | 32 | 53 | 40 | 32 |
| After 12 months at BL | 37 | 58 | 47 | 38 |
| After 12 months at MW | 40 | 56 | 52 | 34 |
| **Reducing Sugars (%)** | | | | |
| At bagging | 0,004 | 0,013 | 0,009 | 0,009 |
| After 12 months at BL | 0,000 | 0,007 | 0,004 | 0,003 |
| After 12 months at MW | 0,005 | 0,840 | 0,006 | 0,004 |

As the moisture content of the sugar increases so does the reducing sugars content, which supports the theory that sucrose is broken down into reducing sugars in the presence of excess moisture. This is particularly obvious in NB sugar stored at MW where levels have increased drastically whereas at BL, where moisture was lost, the reducing sugars content stayed reasonably stable. A good correlation ($r = 0,76$) was found between moisture and reducing sugars content.

Table 3 shows that all the colours have increased steadily over the 12 month period. At MW the increase in colour was statistically significant after 2 months' storage whereas at BL, where humidities are lower, the increases only became significant after 9 months. No correlation was found between colour and moisture contents ($r = 0,20$) or between colour and reducing sugars contents ($r = 0,20$).

*Packaging considerations*

The 3-ply and 4-ply plain paper bags, and to a lesser extent and 3-ply and 4-ply polycoated bags used by HULREF, have been shown to be permeable to the passage of moisture. Thus the sugar stored in these bags was susceptible to the influence of the environment in which it was stored. Sugar stored in the polylined bags was not affected as much by humidity changes, as illustrated by the NB sugar. It was packed at a high moisture content (0,071 %) as well as having a high conglomerate count (89 %) and the sugar began to "sweat" and eventually became very damp and sticky. In the Bloemfontein warehouse, where humidity was low, NB sugar eventually dried out, possibly by passage of moisture through the tuck-in filling spout of the bag.

*Warehousing conditions*

No caking occurred in the low humidity environment of the Bloemfontein warehouse where temperature differences between day and night were kept to a minimum thus not allowing any severe moisture migration. At the beginning of this project it was stated that BL had had serious caking problems at times. It is suggested that the reason these did not occur in the present investigation is that the sugar was packed during a period of fairly low humidity and sent immediately to an even lower humidity environment. If on the other hand the sugar had been packed in a high humidity environment, ie during summer, and stored there for a few weeks before being dispatched to BL, the sugar would have been able to absorb moisture and then to lose it on arrival, causing the severe caking that has been experienced at BL in the past.

*Sugar quality considerations*

The quality of the sugar with respect to moisture content as well as conglomerate count appears to be of importance when considering caking of sugar. For example the NB sugar of high moisture (0,071%) and high conglomerate count (89%) became either damp or caked in all packaging types at MW, while sugar with relatively low moisture content and conglomerate counts (UF, ML and HULREF) did not show these adverse effects.

## Conclusions

The humidity and temperature conditions of the warehouse play a very important role when sugar is packed in moisture permeable material, while the initial moisture content of the sugar is an important factor in the caking potential of sugar packed in moisture impermeable bags.

## Acknowledgements

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## REFERENCES

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2. *Laboratory Manual for S.A. Sugar Factories*, edited by S.A. Sugar Technologists' Association, 1985 (p321, 336, 337, 341).