*Integrated Protection of Stored Produ*
*IOBC Bulletin Vol. 23 (10) 20*
*pp. 79 -*

# Stackburn of stored maize in some sub-Saharan African countries

**A. Maia, G. Barros, A. Mexia**
*Centro de Estudos de Fitossanidade do Armazenamento (CEFA), Instituto de Investigaçã Científica Tropical (IICT), Trav. Conde da Ribeira 9, 1300-142 LISBOA, Portugal*

**Abstract**: The discoloration of stored maize as a direct result of heat build-up in the interior of ba stacks, has emerged, during the last decade in sub-Saharan Africa, as a significant threat of foo security.

As a result of such phenomena, internationally called "stackburn", both local and importe varieties of white and yellow maize can be affected. Maize may be downgraded in commercia markets or have to be diverted to animal-feed use. When discoloration is severe, food aid agencie attempting to distribute stackburned maize may meet beneficiary resistance or rejection and b forced to dispose of large quantities of deteriorated maize at considerable cost.

It is not possible to isolate one primary factor as being responsible for the onset of heatin although the presence of excessive levels of foreign material and internal insect infestation may pla a part in some cases. The introduction and widespread use of woven polypropylene bags, i substitution of jute bags, appears to have contributed to a greater incidence of stack heating.

The constitution of tunnels and chimneys for natural ventilation when building new bagstack came out as a preventive measure

**Key words:** Stackburn, discoloration, heat damage, maize.

## Introduction

In countries of the African continent, generally the packing of cereals, aiming th corresponding storage for variable periods, is predominantly made through sacks. Storage i sacks is adopted in the constitution of stacks of cereals, of variable capacity (50 to 5 000 t not only with the advantage of making the transport easier, but also because it is well suited t the requirements of the local markets.

Besides, under some circumstances characterised by the absence of adequate infra structures for storage, stacking of bagged cereal, outdoors, is the only available way o keeping food reserves during some months. This method of storage is common in som regions of the Sahel and southern Africa.

Recently it has occurred a problem which consists in the heating up of the grain in th interior of those stacks, where the temperature reaches the value of 42°C.

White and yellow maize become discoloured from a light tan though to a dark reddisl brown colour. This phenomena, commonly termed stackburn, has been reported in Angol Ghana, Malawi, Mozambique, Swaziland, Zambia and Zimbabwe.

## Stackburn of stored maize

### *Characterisation*

During storage, due to the action of various factors, conditions that led to stackburn of maize grains may happen. This discoloration may be very intense, being the grains variously coloured, from the opalescent white, normal colour of white maize, passing through light tan, to dark brown.

This phenomenon started to be observed in white and yellow maize in both indoor and outdoor bag stacks in Angola (Boxall and Gough, 1989, 1991), Ghana, Malawi, Zimbabwe (Locke, 1992).

All types of maize grain are susceptible to this alteration (Phillips, 1994), being limited in a first phase to the region of the embryo or germ and in more progressed phases to the pericarp or widespread to the whole grain.

In maize not profoundly altered only the "surface layers" of the embryo and pericarp are affected, staying the core in the original colour. Under other conditions more intense and prolonged, the maize kernel become totally and severely discoloured. To this situation are also associated the characteristic smell close to toasted maize and the fact that the kernel presents more breakable.

This deterioration of the grain makes it inviable as seed, as the percentage germination values are very low. Due to the biochemical alterations undertaken the nutritious value is also reduced.

The word stackburn, originated from Africa, probably from Zimbabwe (Parkin, 1972), express the association of the change of the normal colour of the kernel, with the fact of having occurred in a stack of product contained in sacks as a result of a general heat build up.

### *Occurrence*

In Zimbabwe maize is stored in bulk, in vertical silos, as well as bagged outdoors. In this last case the technique used is called cover and plinth or CAP storage and consists on modular 5 000 t stacks built on a simple dunnage of poles and sheeted over with tarpaulins. At certain times quantities of up to 1,2 million tonnes of white maize are stored outdoors.

Until 1988 the maize was placed into jute bags of 90 kg, but for reasons of economy and convenience of handling, bags of woven polypropylene with the same capacity were introduced (Locke *et al.*, 1993). In 1990, the capacity of each sack was changed to 50 kg.

During the storage season of 1989/1990, it was observed that white maize, in the core of various bag stacks, was discoloured and the opalescent white grains were variously coloured from a light tan colour through to dark reddish-brown. By that time this situation was called "internal stackburn" to make it distinct from another one older and termed "top stackburn" which as the term refers happens in the top of the stacks. This "top stackburn" occurred only in the bags of the top layer of the stacks and immediately underneath the tarpaulins. Even inside each sack the discoloration was restricted to the top layers of the grain.

Kutukwa (1993) refers that "top stackburn" has been noticed, in Zimbabwe, since the first bag depot of the Grain Marketing Board of that country was opened in 1950.

Although the occurrence of "internal stackburn" seems to coincide with the change from jute to woven polypropylene sacks, there are references, like the ones presented by Tyler (1992) and Locke (1992), mentioning that this type of stackburn had occurred in jute sacks, when stored outdoors, but less severely.

Many store managers refer that "top stackburn" happens essentially from September March. This is the rainy season when the values of temperature and relative humidity are hi; and the bag stacks are always covered to avoid the risk of getting wet by the rain. On t opposite, "internal stackburn" occurs earlier.

In Ghana, Tyler and Kutukwa (1993) refer that instead of storing maize outdoors it stored bulk in vertical silos and bagged in stores. When bagged the standard stack is in genei of 300 t, with the dimensions of 8 meters width by approximately 16 layers height. Stackbu was identified in three storage sites, of the Ghana Food Distribution Corporation involvi some 3 000 t out of a total of about 20 000 t.

In one stack of around 250 t of yellow maize imported from United States of Ameri and after 16 months of storage, clear discoloration was revealed in the centre of the partia discharged stack. The cause of this instance may have been dry grain heating although th was also, patchy, mould and insect damage (Tyler and Kutukwa, 1993).

In 1990, maize with a moisture content of around 12.5% $(^m/_m)$ received from four dryi facilities was stored in polypropylene sacks and after five to eight months of storage mai heating was detected together with evident discoloration. In another storage centre of the sai country, the same authors refer that it was also noticed heating in maize bagged in jute a polypropylene sacks in the same stack. The stack was broken down and each sack w examined for temperature, moisture and discoloration.

A significant temperature difference was detected between maize stored in jute sacks a that stored in woven polypropylene bags as they were removed from the centre of the sta Temperatures were higher in individual polypropylene bags (35-40°C) and browning w more noticeable than in adjacent jute bags (30-33°C). The lower three layers of bags and th on the outside of the stack were unaffected. Infestation was not seen (Tyler and Kutukv 1993).

In Malawi, Tyler (1992) and Kennedy and Devereau (1992) refer that this phenome was also detected in maize bagged in woven polypropylene sacks stored in bagstacks in stor

In Zambia around 1 000 000 t of yellow maize were imported, in 1993, from Europe Union and United States of America and stored in 50 kg sacks either of jute or wov polypropylene. The moisture content of that maize was between 14 and 14.5% $(^m/_m)$, and th was not evidence of infestation. During its storage routine fumigations were carry out to av possible infestations.

The maize stored for more than four months were the most affected by stackbu However the maize in the four or five layers of bags on the top and sides of the stack were good quality. A total amount of approximately 95 000 t, was downgraded and sold brewing and animal feed (Walker and Donaldson, 1993).

In Mozambique, 67 500 t of yellow maize were imported, in 1993, from the Europe Union and the United States of America. It was estimated that approximately 50% of tl amount revealed deterioration, after four to eight months of storage, due to stackburn. Gra in both woven polypropylene and jute bags were affected. Stacks were "peeled" to segreg non-discoloured grain and some damage grain was used for animal feed (Conway, 1993; M and Barros, 1994).

In Angola, in the port of Lobito, yellow maize with a moisture content of 14% $(^m/_m)$, food aid imported from Canada, stored in a warehouse in woven polypropylene sacks stacks, revealed after ten months of storage change in the initial colour becoming dark bro (Boxall and Gough, 1989, 1991).

Food aid movements of maize through Tanzania, destined for refugees from Rwanda and Burundi, highlighted the problem of stackburn. Maize in transit in Mombassa and in store on the Rwanda / Burundi borders was downgraded and written off (Taylor, 1996).

### *Causes*

Although stackburn has been recognised in different types of storage systems, it might however have common causes. Of these, the moisture content of maize, at the time of its storage, is considered as the most important and two rather distinct situations may happen.

One, referring to well-dried maize, with a moisture content equal or below 12.5% ($^{m}/_{m}$), which is the situation observed in Ghana, Malawi and Zimbabwe (Kennedy and Devereau, 1992; Tyler, 1992).

The other, regards high moisture contents, above 13.5% ($^{m}/_{m}$), as with food aid maize originated mainly from United States of America, European Union and Canada, where the cases of Angola, Burundi, Mozambique, Rwanda, Swaziland, Tanzania and Zambia may be included.

The monitoring of the temperature, of the moisture content and of possible infestations, undertaken in bagstaks interior, led to the conclusion that the moisture content of the grain is not a significant factor in the initiation of the heating.

Grain respiration, alone, does not seem to have an influence that justifies the observed heating.

However the infestations of the bagstacks, caused by insects, seems to be the most likely cause of stackburn.

To control the insects it is a common practice the use of fumigations. In the particular case of large bagstaks situated outdoors it is required a very special care to achieve total desinfestation. If not the most tolerant insects, in particular immature stages of the species *Sitophilus*, may survive and be responsible for generating the heat that initiate the heating cycle. On the contrary, the survival of insects is not possible if the temperature rises above 42°C.

The process of browning follows the classic Maillard reactions of non-enzymic browning in which, with heat, there are two stages. In the first phase there is no colour change, but the subsequent phase produces a certain degree of browning. Browning affects both the pericarp and the embryo of the maize grain.

The type of material used in the sacks, jute and woven polypropylene, does not only have different characteristics in relation to air and water vapour transmission through the fabrics (New, 1995), but also and consequently on the process of heat transfer in the bagstack (Maia, 1995).

### *Losses*

In Zimbabwe approximately 90% of the commercial downgrade of maize is imputed to stackburn and the remaining 10% to insects and fungi (Kutukwa, 1993). As stackburn could eventually be associated with an inadequate management, discoloured maize have been blended in convenient proportions with maize of better quality in order to allow its commercialisation in upper grades.

This proceeding has been adopted by the depots with vertical silos, where this operation is easily performed. In the depots where storage is in bags, sacks with evidence of stackburn are opened and mixed with maize of good quality. This fact may mask, in part, the true value of the financial losses, making very difficult to get objective estimates of the amounts rea affected by stackburn.

In Zimbabwe, the law that rules the local commercialisation establish a limit of 14% ı damaged grains. The discoloured grains, when added to better quality maize and do ı exceed that limit, are commercialised in that same grade. On the contrary if the quantities ; big, its quality may be so low (grade D) that is exclusively sold for feed. When stackburn very severe, making the maize without any commercial value, it has to be eliminated, bei generally buried or burnt.

Locke (1992) refers that the Grain Marketing Board (GMB) of Zimbabwe estimated one million US dollars the financial losses as the result of the incidence of stackburn 1990/1991. However this estimate may be taken as conservative, once it excludes ı expenditures of the operations of blending, rediverted delivery due to customer rejections a delays in meeting delivery deadlines particularly at ports of loading. It takes only in accou in the commercial downgrade, the maize that left to be exported and the one which had to put out of the market.

During the 1993 regional draught, some 2.5 million tonnes of imported maize v handled by GMB of which some 400,000 tonnes was downgraded due to stackbı deterioration (Giga and Mushongahande, 1996). A loss in value of some US$ 23 million v reported.

In studies made by the Natural Resources Institute of the United Kingdom and the Gr: Marketing Board, in Zimbabwe, to identify the causes of stackburn, a experimental stack o 500 t was built with sacks of 90 kg of white maize being sampled on its constitution. Gr: temperatures and moisture contents were monitored and were related to stack managem procedures and climatic changes.

At the end of the study, after a storage period of 30 months, the stack was systematica broken down and sampled again to enable changes in quality to be determined.

Much of the grain in the core of the stack became discoloured. The proportion of ı more valuable composite A plus B grade dropped from 99% to 53%. C grade rose from 1% 6% and D grade rose from 0% to 30%, whilst 10% became unmarketable due to fun; development. The remaining 1% were weight loss due to insect damage. The total financ loss was calculated to be 13.5% of the stack value, or Zimbabwe $225,880, the equivalent US $42,500 (Locke *et al.*, 1993).

In a similar study also with white maize in a stack of 1 700 t, in sacks of jute a polypropylene of 90 kg of capacity, conducted during 21 months, Donaldson (19! calculated a loss of 4.2% of the stack value, also due to reduction in grade as a result stackburn. This corresponded, also at 1992 prices, to Zimbabwe $76,628, the equivalent to I $14,500.

In Ghana the losses due to stackburn are more difficult to estimate. However, Tyler ε Kutukwa (1993) refer that this problem was identified in three storage depots of the Gr Food Distribution Corporation and 3 000 t out of a total of 20 000 t of maize were affected.

In Zambia without considering the extra costs of segregation and handling of the do graded maize on account of stackburn, it represented a financial loss of some US $30 mill based on the value of the maize landed at Zambia depots during the 1993 draught relief ma (Walker and Donaldson, 1993).

## Conclusions

The common features associated with stackburn in stored maize are:

- recent adoption of woven polypropylene sacks in place of jute sacks;
- maize stored in bagstacks during several months;
- cycle of internal heating up to 40-42°C, affecting particularly the core of the stack, the outer layers being less affected;
- difficulty on detecting the heating in the core of stack by the general inspection methods;
- to the heating cycle follows cooling although renewed heating has also been detected;
- discoloration of the maize grains occurs with no evidence of abnormal insect or fungi damage.

It is not possible to isolate one primary factor as being responsible for the onset of heating, nor to predict with any certainty those combinations of factors which inevitably lead to stack heating of dry maize although the presence of excessive levels of foreign material and internal insect infestation may play a part in some cases. The introduction and widespread use of woven polypropylene bags, in substitution of jute bags, appears to have contributed to a greater incidence of stack heating.

Stackburnt maize does not present a toxicological hazard when used either as human food or animal feed, but nutritive value is adversely affected for all classes of livestock.

Preventive measures came out from the research already conducted and from those the following may be highlighted:

- strict checking of the efficacy of the fumigation carried out;
- constitution of tunnels and chimneys for natural ventilation when building new bagstacks;
- monitoring of the temperature within the stack through the use of simple thermocouples.

## References

Boxall, R. A. and Gough, M. C. 1989: Investigation of technical problems associated with the distribution of food grain from temperate to tropical regions. A study of a shipment of food-aid maize to Angola. Report n°. 4, NRI, Chatham, 71 pp.

Boxall, R. A. and Gough, M. C. 1991: Investigation of technical problems associated with the distribution of food grain from temperate to tropical regions. A study of a second shipment of food-aid maize to Angola. Report n°. 5, NRI, Chatham, 40 pp.

Conway, J. A. 1993: - Technical report on condition of WFP maize stocks in Mozambique and recommendations for their disposal. Report n°. R 2047 (C), NRI, Chatham, 21 pp.

Donaldson, T. J. 1993: A preliminary analysis of stackburn in bagged maize and associated financial losses. Report Project n°. AO227, NRI, Chatham, 45 pp.

Giga, D. P. and Mushongahande, M. 1996: The problem and extent of maize stackburn in Zimbabwe. In: Conway, J. A. (ed.) Investigation on stackburn in national stocks of stored maize in sub-Saharan Africa and its association with increased levels of insect infestation and the introduction of woven polypropylene sacks. Annual Report on

ECDGXII Project Contract TS3*-CT92-0097, Reporting Period: 1 April 199
31 March 1996.

Kenndy, L. and Devereau, A. D. 1992: A comparison of jute and woven polypropylene s
for large scale maize storage. FAO Committee on Commodity Proble
Intergovernmental Group an Jute, Kenaf and Allied Fibres. 28 th Session, Rome, 2
October 1992, 14 pp.

Kutukwa, N. 1993: Maize stackburn in Zimbabwe: Review and current status. Report, G
Marketing Board, Harare, 9 pp.

Locke, M. T. 1992: The cause and prevention of stackburn in stored maize. Area 5: G
quality control. Support to Operations Department Grain Marketing Board, Zimbab
Report n°. R 1828 (C), NRI, Chatham, 15 pp.

Locke, M. T., Donaldson, T. J. and Gough, M. C. 1993: Quality changes in an outdoor s
bagged maize. Report n°. R 2085 (S), NRI, Chatham, 28 pp.

Maia, A. 1995: Analysis of sacks, columns and stacks of sacks of maize cooling b
conductive model. In: Phillips, S. (ed.) Investigation on stackburn in national stock
stored maize in sub-Saharan Africa and its association with increased levels of in
infestation and the introduction of woven polypropylene sacks. Annual Report
ECDGXII Project Contract TS3*-CT92-0097, Reporting Period: 1 April 199
31 March 1995, 50-59.

Maia, A. and Barros, G: 1994: Current status of stackburn in Mozambique. In: Phillips, :
and Donaldson, T. J. (eds.) Investigations into the causes and prevention of heating
discoloration ("stackburn") in bag stored maize. Report, N°.5: EC DGXII Rese
Project Workshop, Harare, Zimbabwe, 6-10 June 1994, NRI, Chatham, 26-30.

New, J. H. 1995: Tests on sack fabrics: air and water vapour transmission through wo
polypropylene and jute. In: Investigations into the causes and prevention of heating
discoloration ("stackburn") in bag stored maize. Report, N°.8: EC DGXII Rese
Project. R2236(S). NRI, Chatham, 32 pp.

Parkin, J. C. 1972: Studies on the fungal deterioration of stored maize in Rhodesia. M
Thesis, University of London, London, 128 pp.

Phillips, S. 1994: Investigation on stackburn in national stocks of stored maize in sub-Saha
Africa and its association with increased levels of insect infestation and the introduc
of woven polypropylene sacks. Annual Report ECDGXII Project Contract. n°. TS
CT92-0097, Reporting Period: 1 April 1993 - 31 March 1994, 131 pp.

Taylor, R. W. 1996: Assessment of losses in contingency stocks of maize supplied to WFP
use in refugee feeding programmes in Tanzania, Burundi, Zaire and Rwanda. Report
R 2317 (C), NRI, Chatham, 18 pp.

Tyler, P. 1992: Heat and discoloration of bagged maize. World Grain, **10** (7): 14-16.

Tyler, P. and Kutukwa, N. 1993: Technical note on a co-ordination visit to Ghana in Octo
1993. Collaborative research project on stackburn. Report n°. R 2042 (C), N
Chatham, 8 pp.

Walker, D. J. and Donaldson, T. J. 1993: Management support to drought relief maize
Zambia. Report n°. R 2037 (C), NRI, Chatham, 39 pp.