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Natural Resources Institute

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Support to Operations Department
Grain Marketing Board, Zimbabwe

AREA 5: Grain Quality Control

The cause and prevention of stackburn in stored maize

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Objectives and Terms of Reference

1. The objective of this consultancy was to ensure that quality control procedures for cereals purchased by the Grain Marketing Board (GMB) are both cost-effective and relevant to modern market requirements. At the request of GMB and with the approval of the GMB/EC Steering Committee the consultant was directed to prepare recommendations to minimise serious losses associated with stackburned maize. Grain marketing losses due to stackburn were estimated by GMB to be in the region of Zimbabwe $3 million.

Summary

2. White maize from the interior of bagstacks, which has been stored for less than 12 months, can be discoloured on despatch. Whilst the moisture content of this maize is considered to be below the level required for 'safe storage', heating of the maize has been recorded. This heating is associated with insect activity which is not always controlled by fumigation. The physical characteristics of polypropylene bags may restrict air and possibly fumigant circulation. Insect movement is obstructed and heat is retained within the stack for long periods. To avoid this build up of heat, consideration should be given to i) fumigating early, ii) ventilating by building tunnels and chimneys into stacks or using fans and iii) reassessing the use of woven polypropylene bags.

Introduction

3. Maize discharged from stacks built from grain held in woven polypropylene sacks for as little as 12 months was found to be seriously discoloured to the extent that the grain was unsuitable for normal distribution and

export. Financial losses were estimated to be in the region of Zimbabwe $3 million.

4. The Research Section of GMB, with technical assistance provided by the UK Natural Resources Institute (NRI) and funded by an EC grant, addressed the problem of preventing or at least minimising stackburn. The consultancy was able to draw on the preliminary results of a collaborative research programme being undertaken by NRI and GMB on the nature and cause of stackburn.

5. Field work was conducted at Concession, Mvurwi, Bindura, Kadoma, Marondera and Aspindale depots and priority was given to interpreting the preliminary research results and preparing management strategies to prevent or minimise losses.

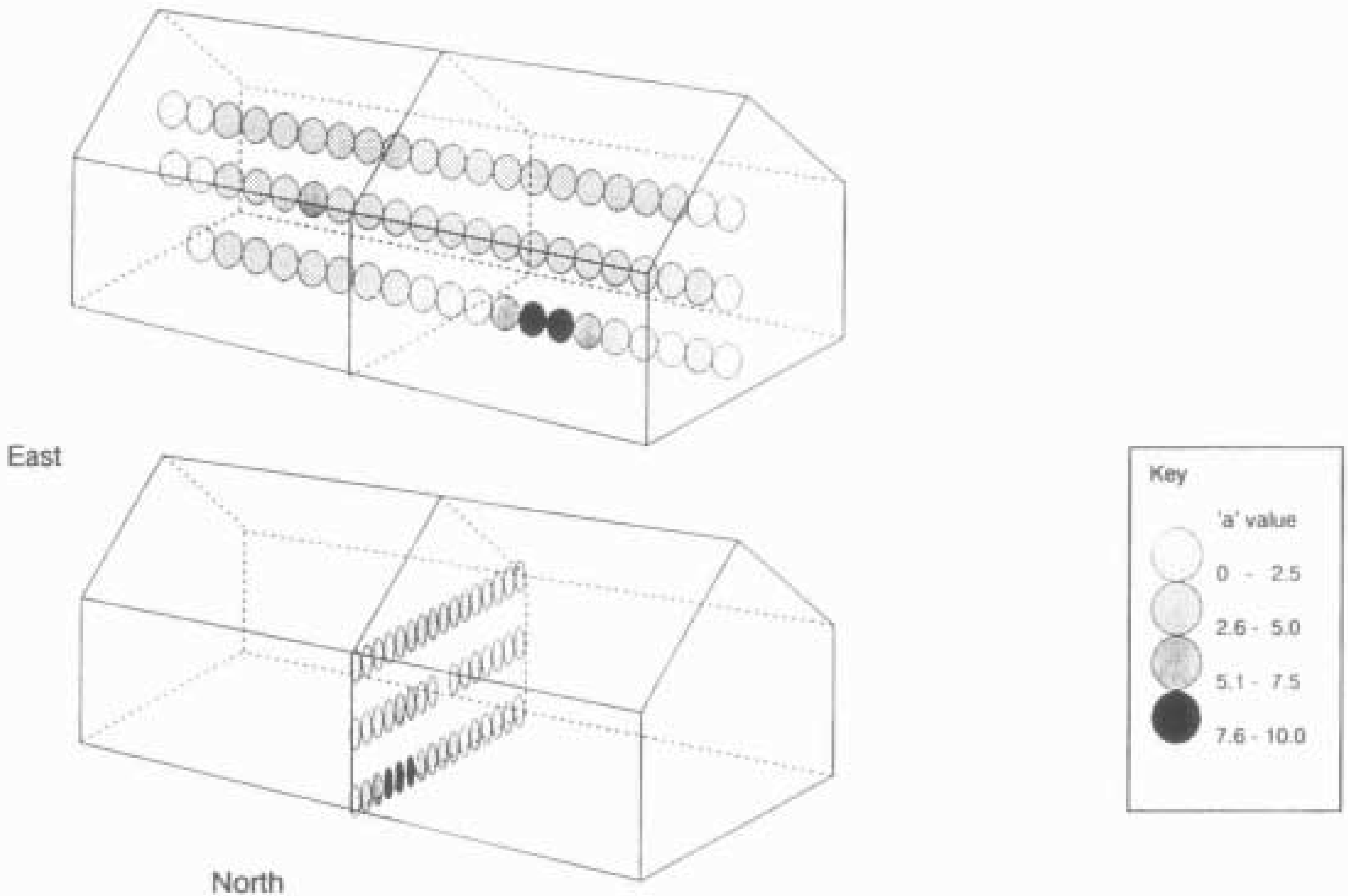
The nature of stackburn

6. Unusual discolouration of the pericarp and embryos of white and yellow maize, known locally as stackburn, has been experienced in both indoor and outdoor bagstacks in Angola, Ghana, Malawi and Zimbabwe.

7. Previous reports of stackburn record grain damage at the top of maize stacks (Parkin, 1972). Preliminary research by NRI and GMB has shown that stackburn is now more common and occurs within the stack (Figure 1). One possible cause of discolouration is non-enzymic browning resulting from complex interactions between temperature, moisture, insect activity and mould growth (Twiddy and Phillips, 1989).

8. Work on rice yellowing in South East Asia has highlighted the importance of improper drying, fungal development and heating leading to discolouration (Phillips *et al.*, 1988, 1989).

Figure 1 : Discolouration of maize in stack 17 at Marondera depot.



9. Accelerated autoclaving tests have shown maize from both communal and commercial areas to be susceptible to stackburn.

Possible causes of stackburn

Intake of wet maize

10. Depot staff would have to accept maize of more than 15% moisture content for wet *grain heating* to begin. There is no evidence, from five experimental outdoor stacks at three depots, to show that the observed heating is associated with intake of grain at high moisture content. *Wet grain heating* is associated with grain temperatures of 55-60°C, at which point fungal populations causing the heat are killed. Temperatures in the experimental stacks rose to 40-43°C after which the maize cooled.

11. Maize at 14-18°C was assigned to the experimental stack at Mvurwi and temperature profiles indicated a substantial rise in temperature to 30-37°C during stack building. The moisture content of the maize at intake was below that at which fungal growth could be expected to take place.

12. A moisture measurement problem was identified arising from incorrect calibration of the GMB moisture meters. This led to meters recording one percent below the actual moisture content and maize at 13.5% may have been accepted for storage. However, this would not have led to grain heating. The problem has been corrected.

Heating due to climatic effects

13. Mean ambient temperature on the Zimbabwe plateau increases by no more than 3-4°C in summer. Solar heating can raise temperatures at stack surfaces to around 50°C,

but the grain cools rapidly at night. The insulation provided by the outer bags in large stacks eliminates solar heating as a cause of the observed rapid rise in internal stack temperature.

Grain embryo respiration

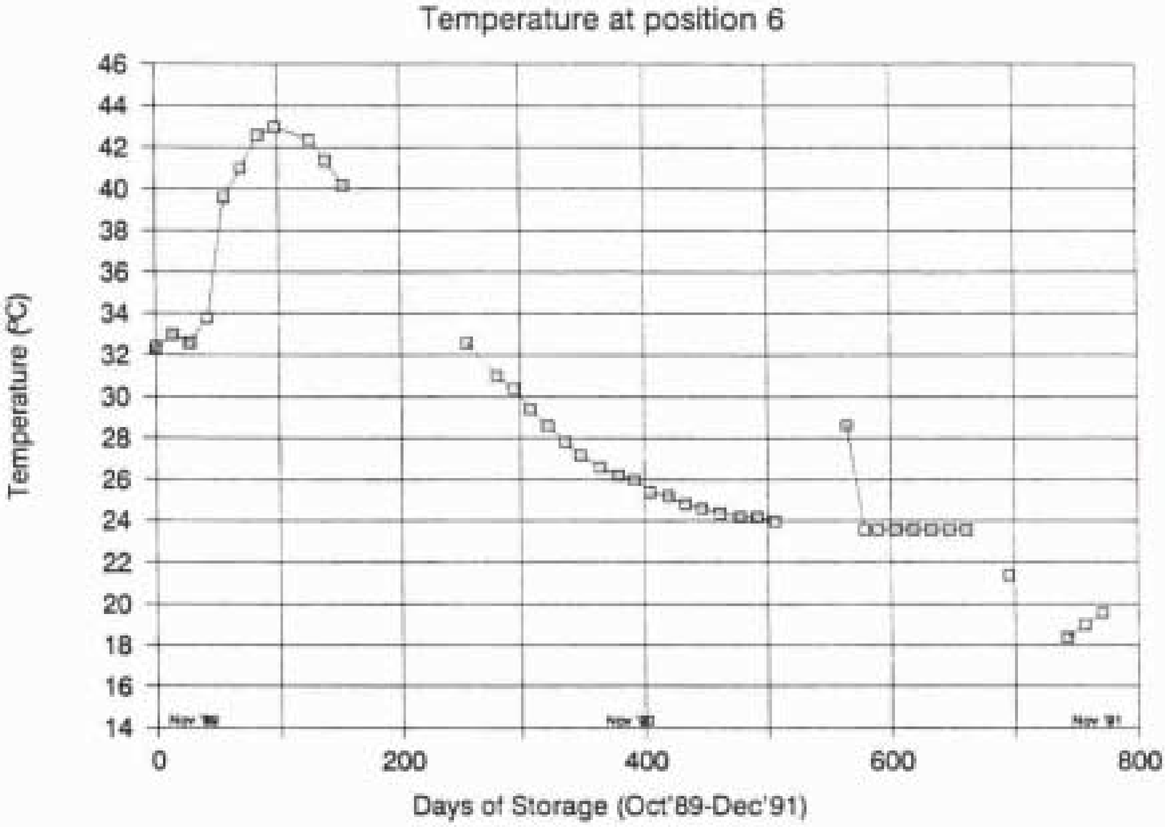
14. Respiratory activity of the embryo of dry grain is low and unlikely to be responsible for the rises in temperature recorded in GMB stacks (Christensen, 1974).

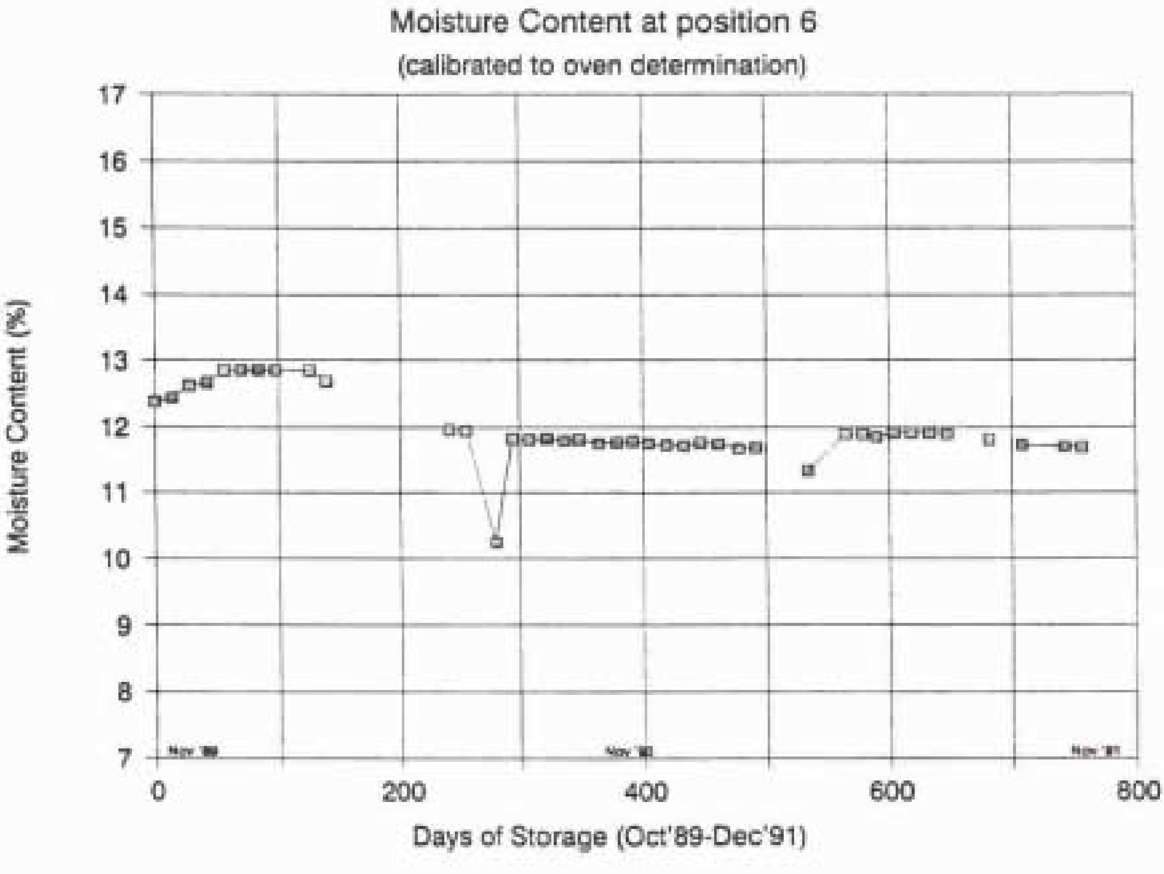
Dry grain heating

15. Laboratory tests indicate that maize discoloured by internal stackburn has the characteristics of grain discoloured by non-enzymic browning. This is a chemical process during which colourless compounds are formed in the grain and react to create a brown pigment. This reaction, the Maillard reaction, is endothermic and therefore requires heat. The moisture content of the grain need not increase above its 'safe storage' level for the process to take place nor is fungal growth required. *Dry grain heating* can result in stackburn if the grain is exposed to heat for a sufficiently long period.

16. Maize tested in the laboratory under a range of moisture and temperature conditions showed varying levels of discolouration. Stackburned maize sampled from observation stacks showed colour equivalent to laboratory samples stored for between three and four months at 11% moisture content and 45°C or at 14% m.c. and 35°C. Readings from a heat sensor embedded in a sack of maize at the centre of a stack showed that a temperature of 40°C was achieved soon after the stack was completed and was sustained for about 100 days. Moisture content at this position ranged from 11.5-13% over time (Figure 2).

Figure 2 : Temperature and moisture content profiles in a central position in stack 16 at Marondera depot.





The source of dry grain heating

Heat and moisture released from expanding insect populations

17. An experimental stack was fitted with sensitive microphones placed 30cm from the temperature sensors. This audio-system was calibrated to record noises made by insect activity. As temperature increased, the number of microphone sites recording noise also increased. When temperatures reached levels lethal to insects, the noises ceased and the temperature began to drop. This provided evidence of insect activity in a region where maize was heating and of the lethal effect of temperatures around 40°C.

18. Based on samples taken from experimental stacks, it has been possible to estimate the quantity of heat and moisture produced by a developing insect population. A conservative estimate of the numbers of adult insects in a 2000 tonne stack at intake is about 100 million. Over one generation (about 37 days) the population could produce two tonnes of water and sufficient heat to raise the temperature of the surrounding grain by 10°C.

19. The micro-climate in the large-scale experimental stacks was similar to the conditions in laboratory experiments which led to the development of stackburn.

20. Moisture and heat generated deep in a stack will be retained for long periods because of the insulating properties of grain. In one stack, internal temperature took 10 months to fall from 43 to 20°C as heat was conducted to the exterior.

Storage in woven tape polypropylene sacks

21. Preliminary observations indicate that maize stored in woven tape polypropylene sacks may be more susceptible to stackburn than maize stored in jute sacks. Stackburned maize, transferred from Mount Darwin to Aspindale, was sampled during despatch from Aspindale. The grains from polypropylene sacks had heavily darkened embryos whereas those from the jute sack did not. There were signs of heavier insect infestation and damage in the maize from the polypropylene sacks.

22. Polypropylene sacks may provide a more suitable environment for *dry grain heating* and the development of stackburn by:

(a) Restricting air circulation - the impermeability of polypropylene and the tight weave of a filled sack could combine to provide a barrier to air circulation. This effect would be particularly marked when gaps in the weave are blocked by the tapes of surrounding sacks.

(b) Restricting insect movement - insects have difficulty moving through the fabric of woven tape polypropylene sacks. The tight weave traps the insects inside the sack and inside the stack.

(c) Restricting release of water vapour - experiments at Kansas State University showed that maize adsorbed and desorbed more moisture in jute sacks than in polypropylene sacks stored under the same air temperature and relative humidity combinations (Guritno *et al.*, 1990). The dangers associated with local accumulation of moisture in grain stored in woven polypropylene sacks would, therefore, increase.

Minimising the effects of stackburn

23. Insect infestations in stacks of bagged maize can provide sufficient heat to start reactions leading to stackburn. The infestations responsible are most likely to be in the maize at intake. Current fumigation procedures are unsatisfactory in providing complete kill of insects (Friendship *et al.*, 1991). This conclusion is supported by data from experimental stacks at Mvurwi and Concession in which heating has continued notwithstanding fumigation using methyl bromide (see Figures 3 and 4). The project is addressing this problem, although the difficulties of effective fumigation of outdoor bag stacks have been highlighted (Harris, 1992).

24. Fumigation should be applied early enough to prevent insect development. However, this will require careful planning. In an experimental stack at Mvurwi Depot, the temperature rose from 18°C at intake to 32°C over a ten day period while the stack was being completed and before fumigation could be applied.

25. There is some evidence to show that ventilation, using mobile fans, can reduce heat in the stack. GMB have implemented for many years a policy of stack aeration by removing stack tarpaulins in good weather. The practice is clearly ineffective in preventing the build-up of heat.

26. A test of fan-assisted ventilation was conducted at Marondera depot and showed that grain can be cooled to temperatures which slow down insect development and biochemical deterioration (Figure 5). Internal stack temperatures were lowered to 18-20°C at which point insect activity is much reduced.

Figure 3 : Temperature profile in a central position in a maize stack at Mvurwi depot.

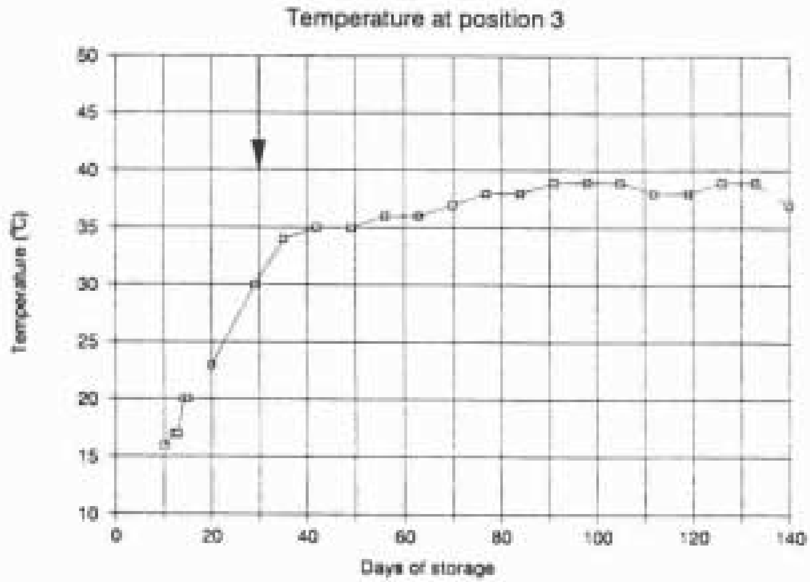


Figure 4 : Temperature profiles in central positions in maize stacks at Concession depot.

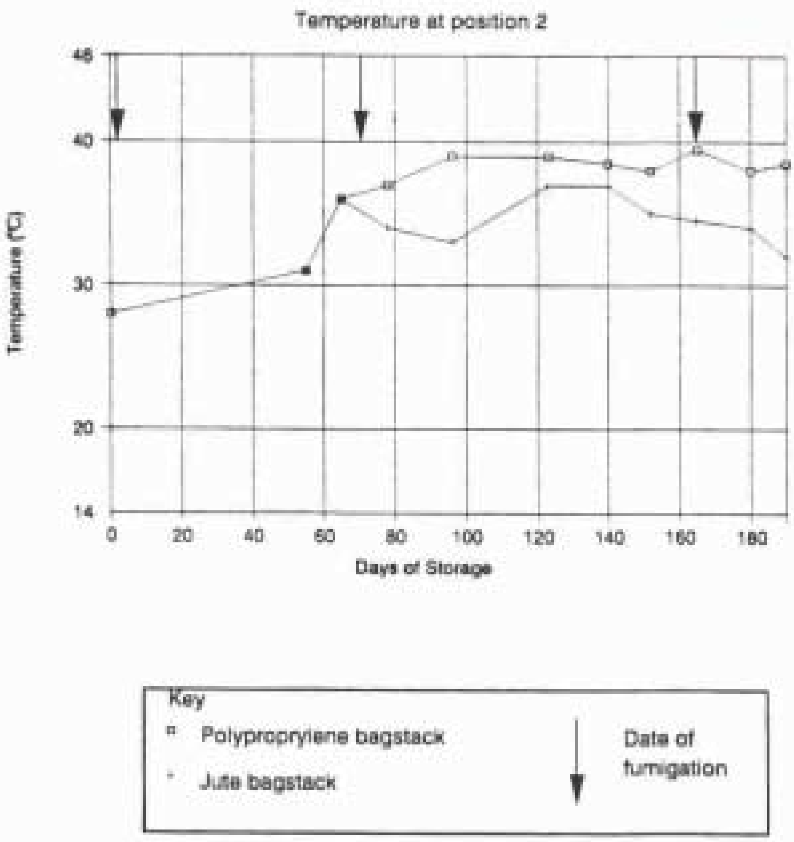
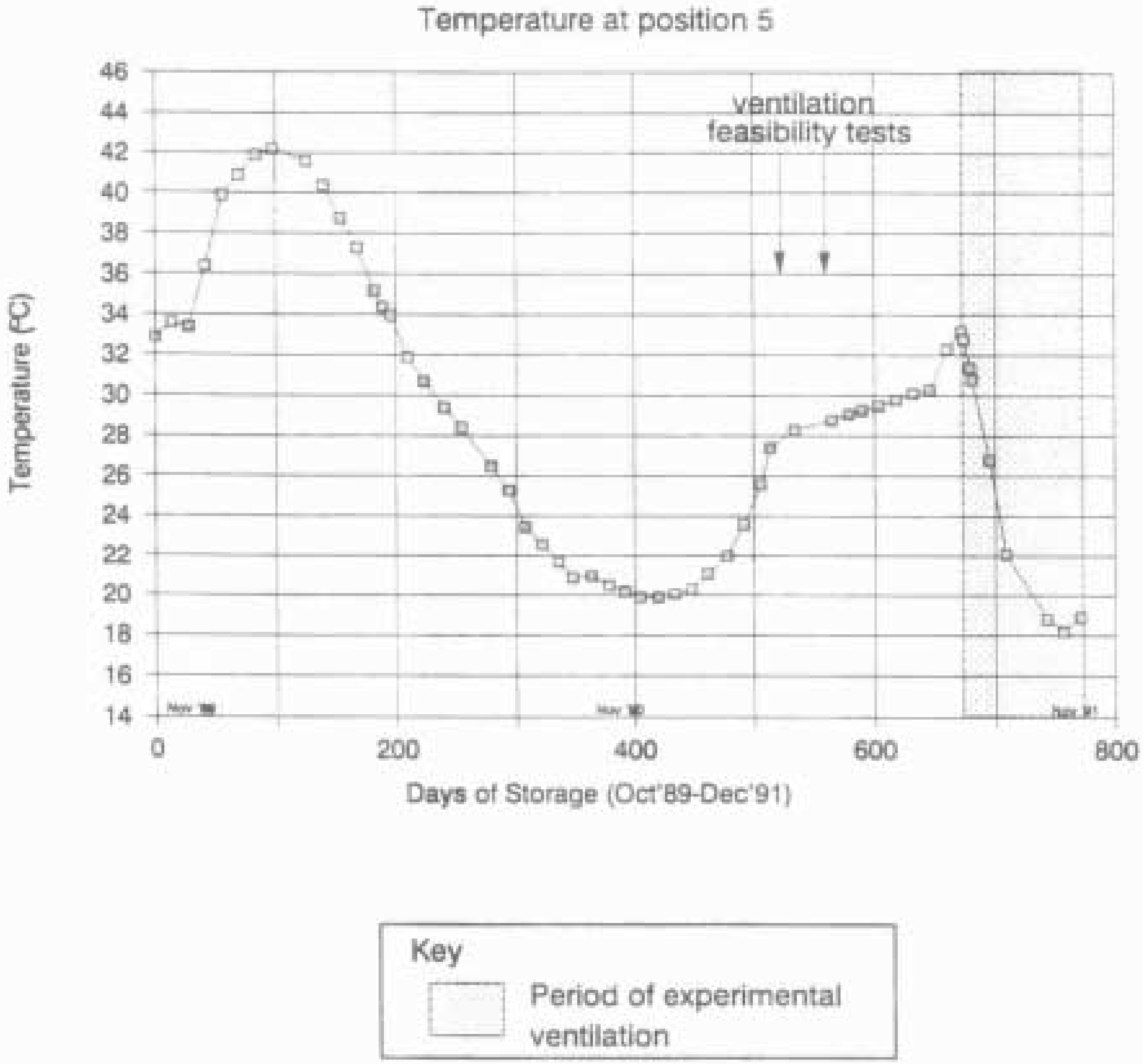


Figure 5 : Temperature profile of a central position during a period of fan ventilation in stack 16 at Marondera depot.



27. Fans were installed on the top of experimental stacks and results suggest that forced ventilation could reduce the risk of stackburn by:

(a) removing heat from the interior of stacks;

(b) accelerating cooling to temperatures below the optimum for insect development (see Figure 5). This has the additional advantage of reducing the need for re-fumigation. As a consequence, costs, losses and chemical residues would be minimised.

28. The rate of removal of heat in this first trial was relatively slow but, now that data from the test are available for analysis, it should soon be possible to make recommendations on practical operating procedures.

29. Jute sacks are being replaced by sacks made from woven polypropylene tape for storage and distribution of food grain in several African countries (Flatman, 1977) and their wider use is being considered. Reasons for the change include substantial savings in foreign exchange and lower storage costs. Polypropylene bags are said to be more resistant to moisture penetration than jute (New, 1987) and commodities stored in them may be less susceptible to mould growth (Odamtten and Kampelmacher, 1986). However, their introduction appears to be associated with an increase in the incidence of stackburn.

30. An additional difficulty has been observed. Polypropylene bags have a lower resale value than jute bags. For example, Blue Ribbon Foods pay Zimbabwe $1.40 for each bag in which maize is delivered to them and re-use the bags for animal feed. Polypropylene bags are more difficult to close and feed products sieve out through the weave. The looser weave has been specified

by GMB in an attempt to allow air currents within a stack to carry off heat and moisture.

31. Importers of Zimbabwe maize are not inclined to accept woven polypropylene sacks which they find slippery and difficult to build into stacks.

32. While it is inappropriate on the basis of this early work to recommend that GMB reverts to the use of jute sacks, it is important to note the potential problems associated with the use of polypropylene.

Conclusions and Recommendations

33. Expanding insect populations, arising from insects present within maize grains at the time of procurement, appears to be a primary source of the heat associated with maize stackburn.

34. Insects within the stacks appear to be surviving methyl bromide fumigation and continue to produce moisture and heat. Recommendations for the improvement of fumigation techniques are currently being implemented (Harris, 1992) to remove this potential source of stackburn.

35. Internal stack temperatures of 35-40°C are associated with stackburn and observations indicate that stackburn may be more widespread in maize stored in polypropylene sacks.

36. There is clearly a need for more work on this storage problem which is of considerable economic significance. The principal areas to verify are:

(a) the effect on temperature and moisture content in stacks incorporating aeration tunnels and chimneys;

(b) the effect of cooling stacks by forced ventilation as a means of postponing refumigation and so reducing costs, losses and chemical residues;

(c) the scale of insect and fungal infestation in maize sold to the Board, thus assisting the development of an optimum strategy and system for maize storage, which includes an assessment of the benefits of applying insect control measures before procurement:

(d) the efficacy of stack fumigation following the GMB/NRI fumigation training programme (Harris, 1992).

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