Effect of storage and thermal treatment on quality of rain-damaged wheat

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Abstract

Quality of rain-damaged grain as measured by Falling Number or Rapid Visco-Analyser (Stirring Number) increases during storage. In contrast, other measures of grain quality, such as mixing properties, decline during storage. Elevated temperature treatments of sound and rain-damaged grain show that the deactivation of alpha-amylase is slower than the degradation in quality as measured by mixing tests. The kinetics of the changes in alpha-amylase activity and grain quality as a function of storage humidity and temperature show that despite a progressive increase in Falling Number/Stirring Number, grain quality as measured by loaf volume progressively decreases. It is concluded that, for baking applications, remediation of rain damage by manipulation of storage conditions is impractical.

Introduction

Rain damage is a serious, if intermittent problem in Australian wheat. In some years, a significant proportion of grain harvested has some degree of rain damage, which renders it less suitable for the production of pan bread, noodles and the production of starch and gluten.

The damage is a consequence of the initiation of the germination process before harvest. Enzymes required for germination are produced initially in the embryo, scutellum and aleurone cells and released into the endosperm. Alpha-amylase and protease both have significant effects. The common salt used in the baking formula inhibits further proteolysis during the baking process. The effects of cereal alpha-amylase are not fully realised until the baking step of the baking process, where it rapidly hydrolyses gelatinised starch. Elevated levels of alpha-amylase result in loaves with reduced volume, poor colour and poor crumb structure.

The extent of rain damage is usually measured with the Falling Number™ test and/or the Stirring Number test, determined with the Rapid Visco-Analyzer (RVA). Both of these instruments measure the effects of alpha-amylase on the viscosity of a starch paste. Both of these instruments effectively measure the amount of alpha-amylase (Hocking et al. 1993).

Long-term storage of sound wheat is associated with gradual decrease in baking performance. This decrease is presumably related to slow changes in the proteins of the wheat during storage, although whether this due cross-linking, oxidation or degradation is not known.

Falling Number (and Stirring Number) of stored grain are known to increase on long storage (H.J. Banks, pers. comm.). This implies that alpha-amylase can be degraded during storage. Presumably, this degradation is chemical process, and the rate of this process can be described by a form of Arrhenius equation, as described for the yellowing of milled rice (Gras et al. 1989; Bason et al., these proceedings).

The use of a brief steam treatment to inactivate enzymes produced as a result of rain damage has been patented (Hutchinson 1967). However, such treatment would be expensive, and has not been widely adopted. By extending the treatment time, the treatment temperature could be reduced and the inactivation carried out during normal, or near-normal storage conditions. If the rate of degradation of alpha-amylase is greater than the underlying deterioration in grain quality, storage may provide a method for the remediation of rain damage.

This paper describes a mathematical model of the rate of change of Stirring Number (and thus for change in alpha-amylase activity) as a function of storage conditions. The change in apparent rain damage resulting from storage has been related to changes in the baking quality of the stored grain.

Experimental

Samples of grain of three wheat varieties, each grown at five locations were selected from the Interstate Wheat Variety Trials of 1992–93. The selection was made to provide a wide range of initial rain-damage in each of three cultivars (Table 1).

For Stirring Number tests, subsamples of each sample were stored in air at each of seven combinations of storage temperature and water activity. Selected regimes were 55°C (water activities of 0.4, 0.6 and 0.8), 35°C (water activities of 0.4, 0.6 and 0.8) and 23°C (water activity 0.6).

Storage experiments were conducted in glass jars continuously purged with air at the same water activity as the stored grain samples and maintained at the desired temperature (±0.5°C). Grain samples were adjusted to the moisture levels appropriate for the desired temperature/water activity before

Table 1. Falling Numbers of samples used in the study.

Growth Site	Cultivar		
	Halberd	Hartog	WW879
Pinnaro	471	481	474
Turretfield	385	386	390
Narrabri	290	134	234
Wagga Wagga	70	62	136
Yanco	256	138	271

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storage, and all water activities were monitored with a humidity meter (Model HMI-31, Vaisala, Helsinki, Finland).

Subsamples were removed for testing at various intervals appropriate for the particular storage regimen. Each was ground on a hammer mill (Falling Number Model 3100).

Falling Number results were determined by the RACI standard method (RACI 1988). Stirring Number results were determined by the method of Ross et al (Ross et al. 1993).

Storage for test baking studies was conducted using samples with low Falling Numbers, supplied by the Australian Wheat Board. Each was stored at 55°C and water activity 0.6. Subsamples (1 kg) were withdrawn from the storage containers after 0, 7, 15, 23 and 69 days. Flour was prepared from these samples using a Buhler Mill. Test baking (120 g flour) was performed in duplicate on each sample by the standard method of the Bread Research Institute of Australia.

The rate of change of Stirring Number was calculated for each combination of storage temperature, storage water activity, variety and growth site. The effects of storage were modelled by multiple regression analysis using MSUSTAT Version 4.0 (Research and Development Institute, Montana State University).

Results and Discussion

Correspondence between Falling and Stirring Number tests

In Australia, the standard test method for detection of rain damage employs the Falling Number method. The newer RVA method uses less sample, and takes less time than the Falling Number method, and the results are well correlated to the results of the Falling Number method (Hocking et al, 1993). The RVA method was therefore used throughout this study. The relation between Falling Number (in seconds) and Stirring Number (in Stirring Number units) for the samples used in this study was determined to be:

Falling Number = 2.92*(Stirring Number) + 9.0

For this relation, the adjusted square of the correlation coefficient was 0.983 for 15 samples, and the standard error of the slope was 0.009. This implies that results obtained with the RVA effectively predict the changes that would be observed with the Falling Number test.

Effect of storage on Stirring Number

At the highest temperature used (55°C), Stirring Numbers results showed a consistent, increasing trend throughout the selected storage periods. Samples stored at water activity of 0.8 changed more rapidly than samples stored at water activity of 0.6, which in turn changed faster than samples stored at water activity 0.4 (Fig. 1).

At 35°C, increases in Stirring Number were evident at water activity 0.8, but the changes observed were minor at 0.4 and 0.6 water activity. These latter experiments, as well as those at 23°C, water activity 0.6, are not sufficiently completed for significant trends to become evident (Fig. 2).

The available data for rate of change of Stirring Number for all fifteen combinations of variety and initial Stirring Number was fitted to a model of the form

$$R = A * e^{B/T} * a_w{}^C \quad (1)$$

where *R* is the change in Stirring Number in Stirring Number units/day,

T is the absolute temperature

a_w is the water activity, and

A, *B* and *C* are constants.

This equation can be converted into a linear form by taking logarithms:

$$\ln(R) = \ln(A) + B/T + C*\ln(a_w) \quad (2)$$

Fitting the available data to this equation showed highly significant contributions by both water activity and reciprocal temperature terms (Equation 3). This equation accounted for 56% of the variance and was highly significant ($P<0.001$).

$$\ln(R) = 24.45 - 7567/T + 1.874*\ln(a_w) \quad (3)$$

Addition of further terms did not improve the fit. Neither the initial Stirring Number, nor the natural log of the Stirring Number were correlated to the rate of change of Stirring Number. This implies that, within the errors of the experiment, the rate of decay of the enzyme is independent of its quantity in the grain.

These figures imply that the increase in Stirring Number (and thus Falling Number) is by factor of approx 2.2 for an increase of 10°C.

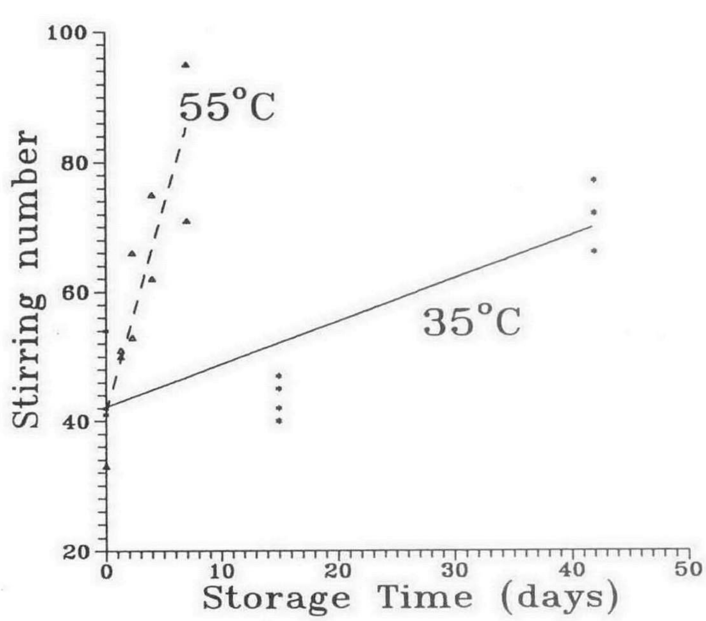

Fig. 1. Change in Stirring Number for cultivar Hartog from Pinnaroo stored at 55°C and three water activities.

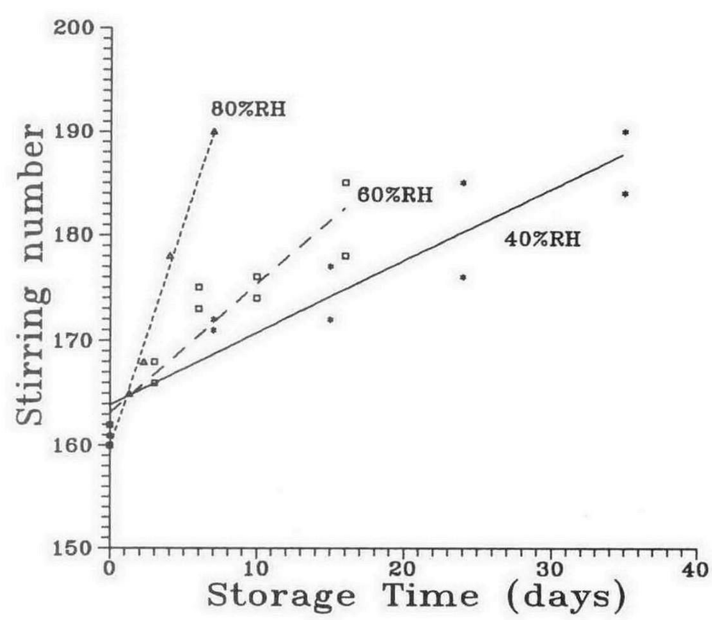

Fig. 2. Change in Stirring Number for samples of WW879 from Wagga Wagga stored at 55°C and 35°C at water activity = 0.8.

Decrease in Stirring Numbers for grain water activity of 0.8 (approx 15% moisture at 25°C) are approx 1.7 times those of grain stored at water activity of 0.6 (approx 11.6% moisture at 25°C.)

The above figures must be taken as preliminary, because significant changes in Stirring Number have so far been observed only in samples stored at 55°C and in samples stored at 35°C and 0.8 water activity. Determination of possible varietal effects must await the completion of the lower temperature–lower water activity storage trials.

Baking properties of stored grain

Test baking studies on larger samples after accelerated storage showed significant increases in Stirring Number. Despite these apparent improvements, there was a progressive decline in overall loaf score (Fig. 3). This behaviour was seen in all damaged grain samples examined.

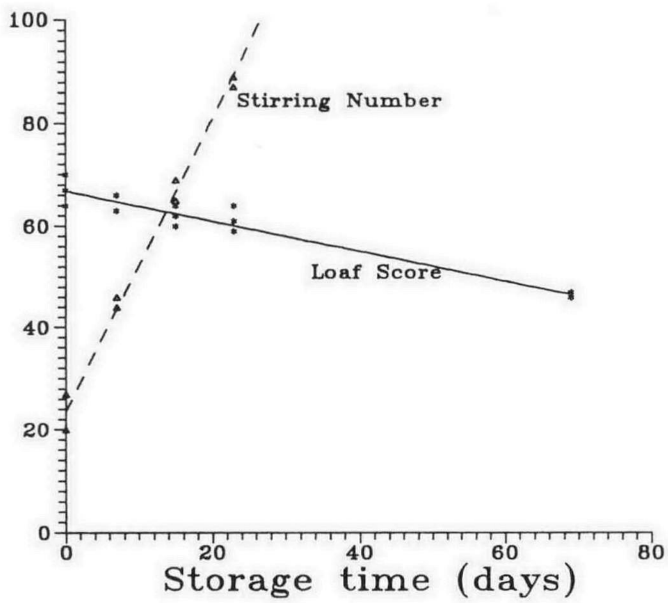

Fig. 3. Relation between Stirring Number and storage time and between Loaf Score and storage time for rain-damaged grain stored at 55°C with water activity of 0.6.

Conclusions

A mathematical model has been developed which will help predict the rates of change of apparent weather damage in stored grain. The results suggest that remediation of rain damage by manipulation of the storage conditions will not improve the baking quality. They also pose a dilemma for grain handling authorities, because in warmer areas, routine storage could increase the Stirring Number (or Falling Number) to allow grain found to be rain-damaged soon after harvest to pass the rain damage test some months later.

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