STORAGE OF MALTING BARLEY (C.V. CLIPPER) IN A NITROGEN ATMOSPHERE

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ABSTRACT

Two lots of malting barley (950 tonnes, c.v. Clipper) were stored under nitrogen (0.5% O_2). One was held for 5 months under nitrogen, the other for 9 months. A third lot was held under normal storage to act as a control. The trial was carried out by The Barley Marketing Board in conjunction with the C.S.I.R.O. Division of Entomology during 1980.

The aim of the trial was to find a lower cost alternative storage method to refrigerated aeration for the medium term storage of malting barley in Queensland. Although tanker-delivered nitrogen gas was used in the trial, and costs were consequently high, it was envisaged the 'lower cost' aim could have been satisfied, in the future, by the use of atmospheres produced by combustion or biological means on-site.

It was concluded that there was neither a significant beneficial nor detrimental effect from the nitrogen atmosphere itself on the germinability of the stored barley. However, there was substantial actual loss of germinability of the grain stored under nitrogen attributable to pregermination.

INTRODUCTION

Queensland's grain growing belt, being in the sub-tropics, has a grain storage environment unique in Australia. This is particularly relevant for the storage of malting barley. High intake temperatures coupled with a warm humid climate for the first few months of storage make the quality preservation in Queensland of barley for malting a rather delicate affair. The important quality parameter, is of course, germination. Barley of low germination obviously cannot be used to produce malt as the malting process is dependent, in simple terms, on the germination of barley, albeit under strictly controlled conditions.

The germination energy of barley, of the cultivar Clipper, unaerated and un-turned, initially at 98%, may gradually drop in storage down to 80% after twelve months. The storage temperature, initially around 30°C, does not normally fall below 20°C within this period. In the past, this problem has been overcome to varying degrees by turning the grain and by use of aeration. However, refrigerated aeration has proved to be the most successful solution to the problem to date. Because it is expensive to refrigerate large masses of grain, an alternative would be desirable.

The object of this trial was to test if storage in an inert atmosphere of 0.5% or less oxygen was viable commercially as an alternative. Although

nitrogen delivered by tanker as a liquid was used in this instance as an inert gas source, it was envisaged that further economies could be obtained in the future by the use of combustion gases or biologically produced atmospheres.

Published information supported the feasibility of use of nitrogen to preserve the germination of malting barley. Glass et al. (1959) showed that in wheat stored at 30°C the onset of deterioration as measured by viability was delayed somewhat by storage in nitrogen as compared with storage in air. Roberts and Abdalla (1968) showed that the oxygen had a deleterious effect on the viability of barley in storage. Shejbal and Di Maggio (1976) in Italy demonstrated that barley at 30°C and 12% moisture lost germinative energy and capacity much faster when stored in air as compared with in nitrogen. Furthermore, Storey et al. (1977) showed that the storage of barley under inert or air atmospheres for six months at 27°C and 50% relative humidity had no adverse effect on the quality of malt produced from the stored barley.

During the trial it was found that the grain designated as a control was not strictly comparable with that stored under nitrogen as the latter had an unexpectedly high level of pregermination. This finding complicated the analysis of the data obtained but also gave information on this poorly recognised factor in commercial barley storage for malting.

MATERIALS AND METHODS

Trial Conditions

At the Barley Marketing Board's Harristown complex, there are eleven white-painted, welded steel bins capable of holding 950 tonnes of barley each. Three of these bins were selected for the trial. Two (designated Bin A and B) were modified prior to inloading so that they were sealable (pressure test:decay time (full), 1500-750 Pa, 7.8 mins each) and possessed a gas introduction system and safety valves. The modifications and gas introduction were carried out according to the procedures given in Banks and Annis (1977). A third bin in the complex, Bin C, was selected for use as a control.

Bins A, B and C were filled with cleaned malting barley (c.v. Clipper) of the 1979/80 crop. Bins A and B were then purged with nitrogen so as to attain an atmosphere within each bin with less than 0.5% oxygen (nitrogen input rates 1.2 and 4.8 m^3, usage 1.26 and 1.01 $m^3\ t^{-1}$ for Bins A and B respectively). Bin A was kept under this low oxygen atmosphere for 5 months and Bin B for 9 months before outloading and sampling. To maintain 0.5% oxygen, it was necessary to continuously bleed nitrogen into both bins. This maintnenance rate varied between 10 L min^{-1} and 40 L min^{1-} at various stages of the trial (average 26 L min^{-1}).

The grain was sampled on the loading of each bin. The loading rate was approximately 100 t h^{-1} with samples and temperature measurements taken every 15 minutes. All samples were tested for moisture content and germination. Selected samples also tested for pregermination precentage. Selected samples were also micro-malted and analysed by two separate malt laboratories, while some commercial malting was also carried out on the barley stored for five months under nitrogen (Bin B).

Analysis Methods

Temperature measurements were made with a thermocouple in the grain stream as each bin was loaded or unloaded.

Moisture contents were determined as per Institute of Brewing Method 1.2 : Moisture Content (oven method: 103°C to 104°C for 3 hours) (Anon. 1977).

Germination percentage was measured as per Institute of Brewing Method 1.4.2 : Germinative Energy (Anon. 1977)

Pregermination level was determined by E.B.C. - Analytica Method 2.6 'A Determination of Pregerminated Grains in Barley' (Anon. 1979).

Malt analyses were carried out in conformity with Institute of Brewing Methods (Anon. 1977).

RESULTS AND DISCUSSION

Table 1 summarises the germination, temperature, moisture content and pregermination data obtained for the three bins during the trial. The grain in each bin showed decrease temperatures of similar magnitude over the trial periods, while moisture content increased slightly in the same proportion in all three bins. Significant germination loss, as is evident from Table 1, was experienced in the two bins held under nitrogen, Bin A and Bin B, while Bin C, normal storage, showed no change in final germination. It is of interest to see an increase in the 24 h germination of Bin C for the 9 month period. It is also important to note here, that Bin C had significantly lower grain temperatures throughout the trial than Bins A and B, possibly enhancing storeability in Bin C.

The substantial loss of germination while under nitrogen was unexpected. Two approaches were adopted in an attempt to explain the observation. Firstly, all inloading and outloading samples were retested so that comparisons could be made between samples held in the laboratory and

Table 1 Analysis of quality of bin, before and after storage.

Quality Parameter	5 MONTH TRIAL						9 MONTH TRIAL					
	Bin B (N_2)			Bin C (Air)			Bin A (N_2)			Bin C (Air)		
	Jan 80	Jun 80	% change	Jan 80	Jun 80	% change	Jan 80	Oct 80	% change	Jan 80	Oct 80	% change
Moisture Content (%)	11.9	12.3	+3	12.0	12.3	+3	11.8	12.2	+3	12.0	12.3	+3
Temperature (°C)	28.3	21.0	-26	26.7	19.4	-27	30.1	22.4	-26	26.7	17.8	-33
Germination (%)												
4 ml-												
24 h	80.6	61.4	-24	78.7	69.4	-11	82.0	58.3	-29	78.7	86.5	+10
48 h	93.3	83.6	-10	95.8	90.5	-5	94.7	80.7	-15	95.8	95.6	0
72 h	94.7	88.2	-7	97.3	96.1	-1	96.7	85.7	-11	97.3	97.2	0
8 ml-												
72 h	52.7	77.7	+48	54.2	88.0	+62	57.5	64.0	+12	54.2	87.7	+62

Table 2. Mean germination and pre-germination. Analysis by bin.

		Moist-ure content (%)	Temper-ature (°C)	Observation soon after sampling Germination tests 4 ml 24 h	4 ml 48 h	4 ml 72 h	8 ml 72 h	Retest after laboratory storage Germination tests 4 ml 24 h	4 ml 48 h	4 ml 72 h	8 ml 72 h	Pre-germin-iation (%)
Mean	Bin A	11.8	30.1	82.0	94.7	96.4	57.5	48.1	71.3	77.9	50.5	7.2
STD Dev	Initially	0.6	5.6	4.5	3.8	1.4	15.0	15.9	15.6	13.3	18.7	4.7
No. Samples		46	45	47	47	47	47	27	27	27	27	27
Mean	Bin A	12.2	22.4	58.3	80.7	85.7	64.6	42.4	64.3	74.8	47.8	3.9
STD Dev	After 9 mth	0.4	2.8	13.5	12.9	9.8	15.7	17.8	18.9	18.5	19.2	2.9
No. Samples	storage under N_2	42	42	42	42	42	42	42	42	42	42	42
Bin B Mean	Bin B	11.9	28.3	80.6	93.3	94.7	52.5	60.6	75.7	79.5	61.8	3.4
STD Dev	Initially	0.8	2.7	13.2	9.9	8.7	11.6	25.8	22.9	20.4	24.8	4.1
No. Samples		40	41	41	41	41	41	19	19	19	19	19
Bin B Mean	Bin B	12.3	21.0	61.4	83.6	88.2	77.7					
STD Dev	After 5 mth	0.9	2.6	21.2	18.1	15.4	20.3					
No. Samples	storage under N_2	40	39	40	30	30	40					
Bin C Mean	Bin C	12.0	26.7	78.7	95.8	97.3	54.2	74.1	90.0	93.8	73.5	0.8
STD Dev	Initially	0.7	4.9	5.2	2.6	1.8	11.6	6.2	4.9	3.8	16.7	1.4
No. Samples		46	46	46	46	46	46	32	32	32	32	32

Table 2 (continued)

		Moist-ure content (%)	Temper-ature (°C)	Observation soon after sampling Germination tests 4 ml 24 h	4 ml 48 h	4 ml 72 h	8 ml 72 h	Retest after laboratory storage Germination tests 4 ml 24 h	4 ml 48 h	4 ml 72 h	8 ml 72 h	Pre-germin-iation (%)
Bin C												
Mean	Bin C	12.3	19.4	69.4	90.5	96.1	88.0					
STD Dev	After 5 mth	0.5	1.9	19.4	5.5	2.7	5.3					
No. Samples	storage	48	48	48	48	48	48					
Bin C												
Mean	Bin C	12.3	17.8	86.5	95.6	97.2	87.7	64.8	89.0	96.2	73.1	0.7
STD Dev	After 9 mth	0.4	0.6	5.1	2.8	1.7	5.3	10.7	4.7	1.8	7.4	1.1
No. Samples	storage	28	26	28	28	28	28	28	28	28	28	28

grain stored in the bins. Secondly the sampling profiles of the grain from the bins were examined, isolating comparable zones for micro-malting work and more definitive comparison of effect of storage atmosphere.

The average germination of samples of barley taken from Bins A,B and C measured soon after sampling, were compared with that for the same samples stored under laboratory conditions (dry, in paper packets, air conditioned area) until March 1981. The results are shown graphically in Fig. 1.

It can be seen that the grain in each bin is significantly different in terms of storage potential and that the germination decline in the barley stored in the bins under nitrogen was similar with that stored in the laboratory. It can be concluded that the storage method did not influence the retention of germinability appreciably.

Bin Profiles

Germination profiles for each bin are shown graphically in Figs. 2, 3 and 4. As can be seen by comparing initial loading results and fifteen month re-test results, some parcels of grain exhibited a substantial potential for loss of germination. In fact, both Bins A and B contained parcels of grain which were initially low in germination and progressively got worse. As luck would have it, Bin C, the control bin, contained no parcels of grain with an inherent potential for germination decline.

An attempt was made to account for this 'germination loss' potential by testing all available samples for pre-germination percentage. These results are also shown graphically in Figs. 2, 3 and 4 and, at the best, show only a casual relationship with viability decline. A more definite relationship is evident from the mean results for each bin (Table 3). Additional pre-germination data is given in Table 2.

Table 3 Pregermination levels before and after storage under laboratory conditions (4 ml test, 72 h assessment)

	On Inloading	After Lab. Storage		
Bin	Germination at Jan 80 %	Germination at Mar 81 (%)	Loss rate (% per mth)	Pregermin -ation (%)
Bin A	96.4	77.9	1.23	7.2
Bin B	94.7	79.5	1.01	3.4
Bin C	97.3	93.8	0.23	0.8

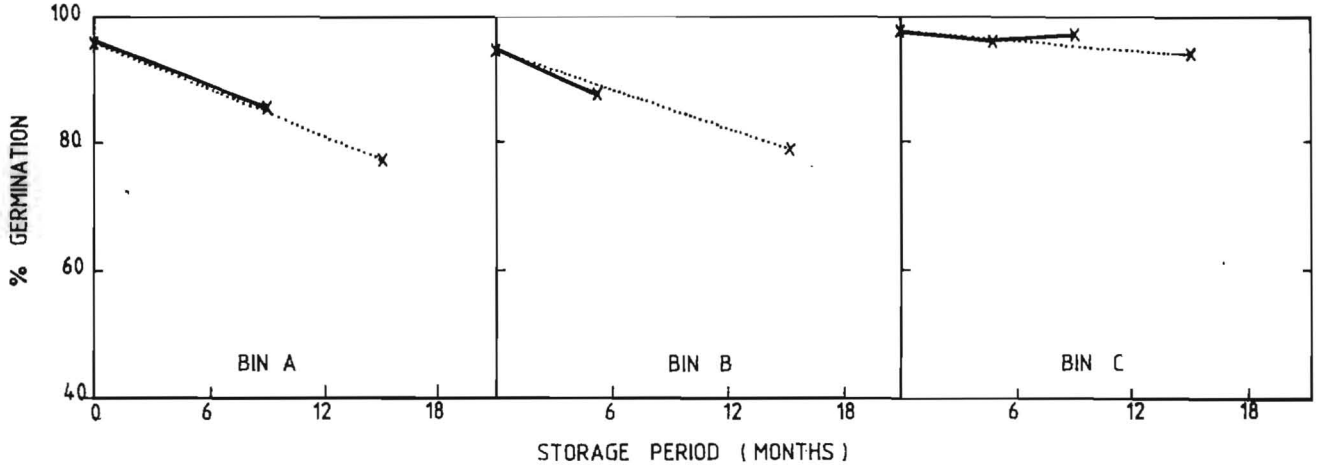

Fig. 1 Germination decline - bin storage (-) vs. storage in laboratory (.....). 4 ml test, 72 hr assessment.

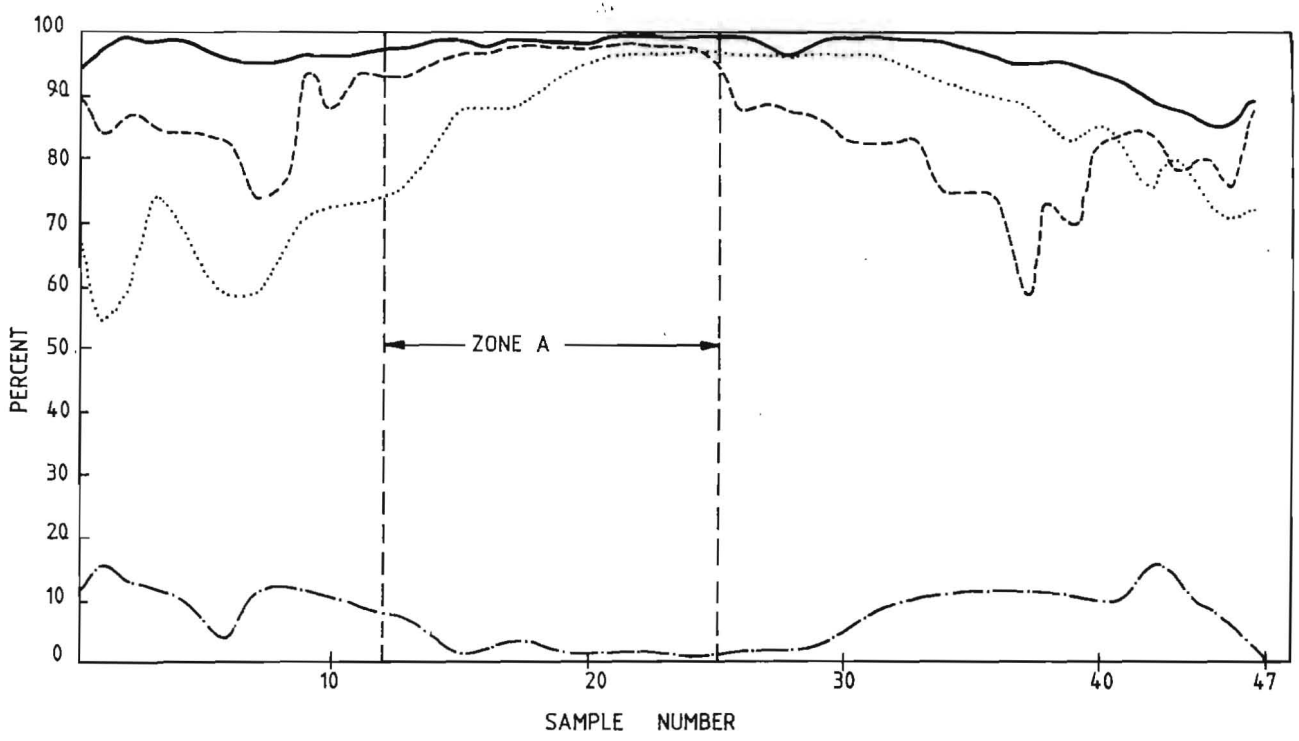

Fig. 2 Profile of germination and pregermination (-.-.) for Bin A. 4 ml test, 72 hr assessment (-, on loading; -----, after 9 months storage under nitrogen; ....., on-loading samples stored in laboratory).

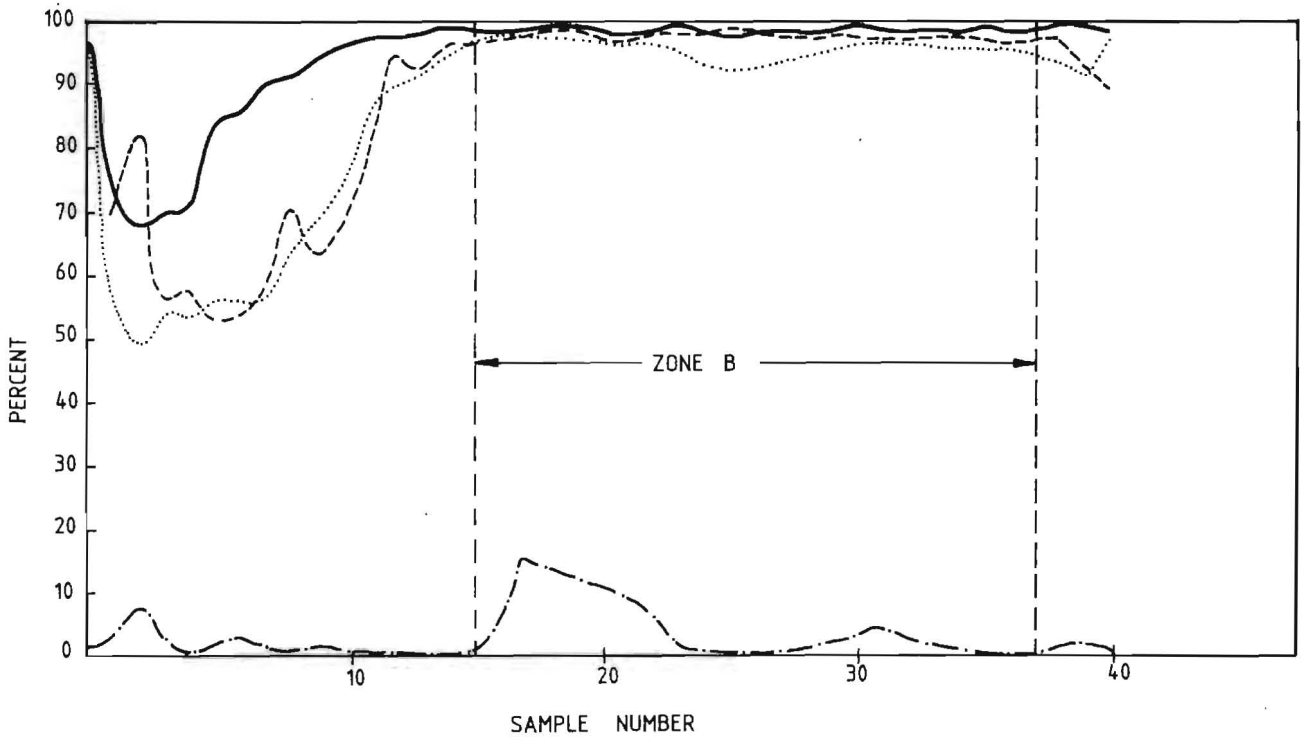

Fig. 3 Profile of germination and pregermination (-.-) for Bin B. 4 ml test, 72 hr assessment. (-, on loading; -----, after 5 months storage under nitrogen; ....., on-loading samples stored in laboratory).

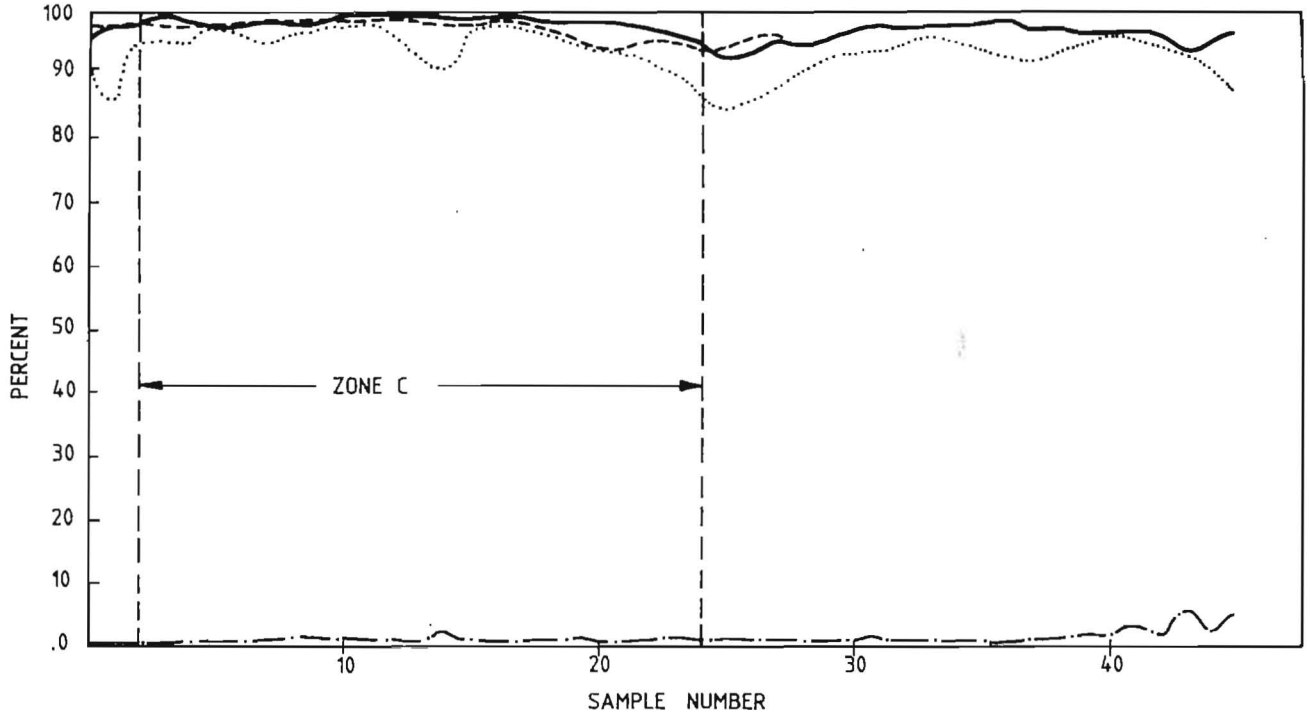

Fig. 4 Profile of germination and pregermination (-.-.-) for Bin C. 4 ml test, 72 hr assessment. (-, on-loading; -----, after 9 months storage; ....., on-loading samples stored in laboratory).

In carrying out the pregermination testing, problems of reproducibility were encountered and this may well have hindered conclusive definition of casual relationship between pregermination and germination loss.

It is interesting to note here that the only comparable work done by us on grain stored under refrigerated aeration shows a loss rate of 1.19%/mth with a pregermination level of 17.2% (Appendix 1).

Zoning

Because of the variation in germination of the samples the concept of zoning was introduced, so that comparable grain could be isolated for micro-malting analysis. Grain samples on inloading and outloading were labelled as to which portion in the bin they represented. Given that the bins emptied from the top and the grain flow was at a constant rate, then it was considered probable that certain zones could be identified as the grain was transferred from one bin to another. The other proviso was that a zone should not involve any of the first three or last three samples of a transfer as it was logical to expect a certain amount of mixing here. The zone in Bin C was isolated because part of that bin had to be outloaded in June for reasons external to the trial.

The zones selected are shown in Figs. 2, 3 and 4, with the zone limits based on fifteen month re-test data and pregermination data from the laboratory - stored samples. Table 4 gives data similiar to that shown in Table 1, but with the analysis by zone rather than by bin. As can be seen from Tables 4 and 5 there is little difference between the germination (4 ml - 72 h) results of the treated and untreated zones after either 5 or 10 months of storage under nitrogen. Further data on grain from Zones A, B and C is given in Table 5. Of some interest in the results from 9 months storage under nitrogen is the fact that the percentage increase in 8 ml data is significantly less than the air control. Also, it is still of interest to see the 4 ml - 24 h results with a positive value for Bin C after 9 months storage.

Malt Analysis

Micro-malting and subsequent malt analysis was carried out by two malt laboratories on barley from Zones A, B and C. We were also fortunate to obtain the malt analysis of commercial malt produced from Bin B in two separate malthouses. The micro-malting work is summarised in Table 6 while Table 7 shows the results of commercial malt produced from barley stored for 5 months under nitrogen compared with standard control malts for the respective malthouses.

As can be seen from both tables, the storage under nitrogen had no adverse affects on subsequent malt quality. In fact, it is encouraging to

Table 4. Analysis of quality by zone.

Quality parameter	5 MONTH TRIAL						9 MONTH TRIAL					
	Zone B (N_2)			Bin C (Air)			Zone A (N_2)			Zone C (Air)		
	Jan 80	Jun 80	% change	Jan 80	Jun 80	% change	Jan 80	Oct 80	% change	Jan 80	Oct 80	% change
Moisture content (%)	11.4	11.8	+4	12.0	12.3	+3	11.8	11.9	+1	11.8	12.3	+4
Temperature (°C)	28.0	20.8	-26	26.7	19.4	-27	29.8	25.5	-14	26.8	17.9	-33
Germination (%)												
4 ml-												
24 h	87.0	73.7	-26	78.7	69.4	-12	84.5	73.6	-13	82.1	87.2	+6
-48 h	97.7	95.0	-13	95.8	90.5	-6	97.9	93.9	-4	97.1	96.1	-1
-72 h	98.6	97.7	-1	97.3	96.1	-1	98.9	96.6	-2	98.2	97.3	-1
8 ml-												
72 h	57.6	89.4	+55	54.2	88.0	+62	70.6	82.1	+16	56.1	87.3	+56

Table 5 Mean germination and pre-germination. Analysis by zone.

		Moist-ure content (%)	Temper-ature (°C)	Observation soon after sampling Germination tests 4 ml 24 h	4 ml 48 h	4 ml 72 h	8 ml 72 h	Retest after laboratory storage Germination tests 4 ml 24 h	4 ml 48 h	4 ml 72 h	8 ml 72 h	Pre-germin-iation (%)
Zone A												
Mean	Before	11.8	29.8	84.5	97.9	98.9	70.6	61.1	84.7	89.4	68.5	1.7
STD Dev	treatment	0.5	1.1	3.5	1.1	0.9	9.0	9.0	9.6	7.8	19.2	2.4
No. Samples		14	12	14	14	14	14	6	6	6	6	6
Zone A												
Mean	After	11.9	25.5	73.6	93.9	96.6	82.1	63.9	86.9	93.5	69.3	2.7
STD Dev	9 mth storage	0.4	0.8	5.3	3.8	1.5	6.3	10.1	5.7	4.5	9.4	2.1
No. Samples	under N_2	12	12	12	12	12	12	12	12	12	12	12
Zone B												
Mean	Before	11.4	28.0	87.0	97.7	98.6	57.6	82.1	95.2	97.0	82.1	5.0
STD Dev	treatment	0.4	1.4	3.1	0.9	0.6	10.0	3.8	2.8	2.3	5.0	5.9
No. Samples		23	23	23	23	23	23	7	7	7	7	7
Zone B												
Mean	After	11.8	20.8	73.7	95.0	97.7	89.5					
STD Dev	5 mth storage	0.3	2.1	6.0	1.9	0.7	4.4					
No. Samples	under N_2	23	23	23	23	23	23					

Table 5 (continued)

Zone C											
Mean	Initially	11.8	26.8	82.1	97.1	98.2	56.1	76.1	93.0	95.8	82.6	0.3
STD Dev		0.5	0.9	3.5	1.7	1.2	14.0	5.3	3.1	2.5	6.6	0.6
No. Samples		22	22	22	22	22	22	15	15	15	15	15
Zone C											
Mean	After	12.3	85.7	95.2	98.0	91.6	18.8					
STD Dev	5 mth storage	0.4	3.5	2.3	1.1	3.1	2.1					
No. Samples		22	22	22	22	22	22					
Zone C												
Mean	After	12.3	17.9	87.2	96.1	97.3	87.3	66.4	89.5	96.4	73.4	0.7
STD Dev	9 mth storage	0.4	0.6	2.9	1.9	5.3	5.3	11.0	5.1	2.0	7.7	1.2
No. Samples		22	20	22	22	22	22	22	22	22	22	22

Table 6 Micro - Malting Results for barley stored in air and under nitrogen.

Laboratory	Zone	Barley Sampling date	% Extract (dry)	Modification index (%)	Diastase (^{o}L)
Laboratory 1 (0.1 ppm GA + 100 ppm bromate)	Zone A	Initially Jan 80	77.5	33.9	65
	"	After Storage Oct 80	78.3	34.6	67
	Zone B	Initially Jan 80	77.0	32.9	68
	"	After storage Jun 80	78.1	37.7	76
Laboratory 2 (0.2 ppm GA + 150 ppm bomate)	Zone A	Initially Jan 80	81.0	44.1	77
	"	After storage Oct. 80	80.9	43.9	78
	Zone B	After storage Jun 80	81.3	50.6	86
	Zone C	Initially Jan 80	82.5	52.4	80

Table 7 Commercial Malting Results for barley stored for 9 months under nitrogen.

Malthouse	Barley	% Extract (dry)	Modification index (%)	Diastase (^{o}L)
Malthouse 1	Zone B	85.4	44.8	74
	Malthouse control	84.5	48.4	63
Malthouse 2	Zone B	79.1	37.7	79
	Malthouse control	79.0	37.1	69

note, that the malt enzyme parameter, diastase, is higher for the 'nitrogen' barley in every case where a comparison can be made.

CONCLUSIONS

Although inert atmosphere storage of barley has no detrimental effects on the malting quality of that barley, it has no advantage over the present techniques employed for the medium term storage of malting barley in Queensland.

This trial has indirectly produced evidence which more positively identifies pregermination as a factor in germination decline of barley in commercial storages.

ACKNOWLEDGEMENTS

This trial work was sponsored by The Barley Marketing Board (Q'land) and without support from senior Management and Board Members would not have been possible. Dr. Jonathan Banks provided the inspiration, the impetus, and certainly a large part of the energy required to conduct this trial and for this, I thank him very much.

Thanks must also go to the following companies and organisations and their staff for assistance in this project: C.S.I.R.O. Division of Entomology, The Commonwealth Industrial Gases Limited, Carlton and United Breweries Limited, Queensland Malting Company Pty Limited and Barrett Burston (Australia) Limited.

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APPENDIX 1

Pregermination levels and germination tests for barley (c.v. Clipper) stored for 7 months under refrigerated aeration (Brookstead, 80/81 season).

Sample	Moisture content (%)	Temperature (°C)	Germination 4 ml test 24 h	48 h	72 h	Pre-germination (%)
A 4	10.2	17.6	68	86	94	34
A 8	10.7	17.2	75	91	93	25
A12	10.9	17.6	74	92	97	16
A16	10.9	17.3	68	86	92	27
A20	9.6	18.3	65	82	89	26
A24	10.6	17.9	77	88	92	25
A28	10.2	17.9	61	84	90	30
A32	9.9	19.6	73	85	88	31
A36	10.8	18.9	72	82	90	29
A40	10.1	18.3	55	86	92	23
A44	10.6	18.2	60	91	93	31
A48	10.1	17.4	77	91	94	13
B 4	11.2	13.6	66	86	91	9
B 8	10.6	13.4	75	86	93	8
B12	10.1	13.1	73	87	82	9
B16	9.9	12.9	75	86	93	9
B20	9.8	12.6	68	91	94	10
B24	10.2	13.2	72	87	90	10
C 4	10.6	12.3	71	82	90	12
C 8	9.8	12.6	74	87	84	34
C12	10.2	12.3	28	79	92	22
C16	11.1	11.7	75	86	90	14
C20	10.6	11.2	76	86	91	17
C24	9.8	10.6	73	83	84	4
D 4	10.9	12.3	65	77	88	5
D 8	10.7	12.6	69	84	89	11
D12	10.7	11.7	74	87	91	10
D16	10.5	11.4	70	87	96	4
D20	10.4	11.6	75	86	93	10
D24	10.2	10.7	80	93	97	9
Mean	10.4	14.5	69.5	86.1	91.7	17.2
STD. DEV.	0.4	3.0	9.6	3.7	2.3	9.8